PATENT ABSTRACTS OF JAPAN

(11)Publication number : 09-091949
(43)Date of publication of application : 04.04.1997

(51)Int.Cl. G11C 11/14

(21)Application number : 07-244991
(22)Date of filing : 22.09.1995

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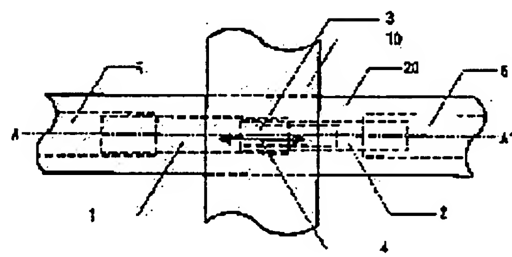
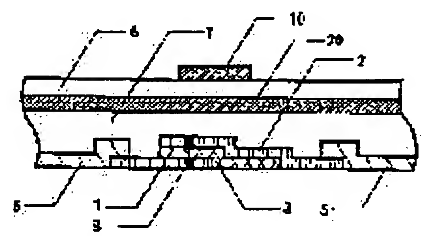
(54) MAGNETIC THIN-FILM MEMORY ELEMENT AND MAGNETIC THIN-FILM MEMORY

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain a magnetic thin-film memory element and a magnetic thin- film memory whose structure is simple, whose resistance and power loss are low, and whose capacity can be increased by providing a part with a different coercive force between magnetic layers and tunnel effect.
SOLUTION: A first magnetic layer 1 and a second magnetic layer 2 with parallel axes of easy magnetization are laminated while holding an insulation layer 3 in-between and are connected to a read line 5. The coercive force of the second magnetic layer 2 is larger than that of the first magnetic layer 1 and there is a part for obtaining tunnel effect between the first magnetic layer 1 and the second magnetic layer 2.





LEGAL STATUS
[Date of request for examination] 25.05.2000
[Date of sending the examiner's decision of rejection]
[Kind of final disposal of application other than the examiner's decision of rejection or application converted

registration]

[Date of final disposal for application]	
[Patent number]	3333670
[Date of registration]	26.07.2002
[Number of appeal against examiner's decision of rejection]	
[Date of requesting appeal against examiner's decision of rejection]	
[Date of extinction of right]	

(19) 日本国特許庁 (JP)　(12) 公開特許公報 (A)　(11) 特許出願公開番号

特開平9－91949

(43) 公開日　平成9年 (1997) 4月4日

(51) Int. Cl.⁶	識別記号	庁内整理番号	F I		技術表示箇所
G11C 11/14			G11C 11/14	A	

審査請求　未請求　請求項の数5　OL　(全12頁)

(21) 出願番号　特願平7-244991

(22) 出願日　平成7年 (1995) 9月22日

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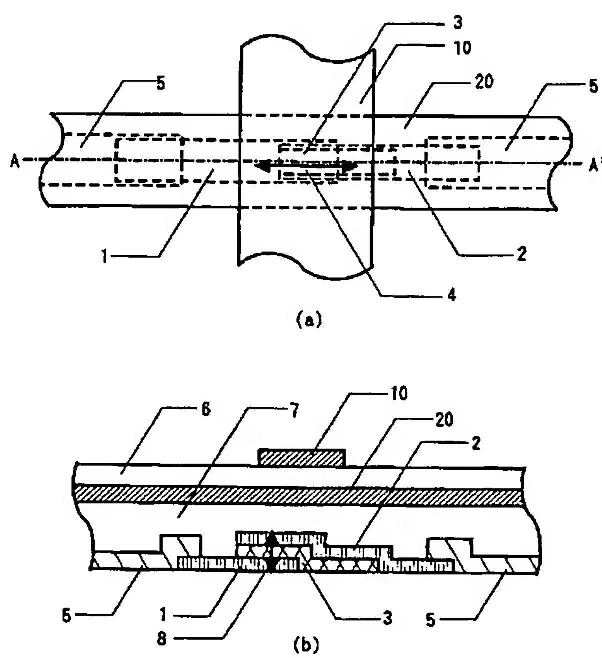
(54) 【発明の名称】磁性薄膜メモリ素子及び磁性薄膜メモリ

(57) 【要約】
【課題】　構造が単純な3層構造からなり、低抵抗でパワーロスが少なく、大容量化が可能な磁性薄膜メモリ素子および磁性薄膜メモリを提供することを目的とする。
【解決手段】　絶縁層を挟んで積層された、磁化容易軸が平行な第1磁性層及び第2磁性層を有し、該第2磁性層の保磁力は、該第1磁性層の保磁力より大きく、該第1磁性層と該第2磁性層との間で、トンネル効果が得られる部分があることを特徴とする磁性薄膜メモリ素子。



(a)
(b)

【特許請求の範囲】

【請求項１】　絶縁層を挟んで積層された、磁化容易軸が平行な第１磁性層及び第２磁性層を有し、該第２磁性層の保磁力は、該第１磁性層の保磁力より大きく、該第１磁性層と該第２磁性層との間で、トンネル効果が得られる部分があることを特徴とする磁性薄膜メモリ素子。

【請求項２】　請求項１記載の磁性薄膜メモリ素子に於いて、絶縁層の材料としてダイヤモンドライクカーボンを用いたことを特徴とする磁性薄膜メモリ素子。

【請求項３】　請求項１記載の磁性薄膜メモリ素子に於いて、絶縁層の材料としてポリパラキシレンを用いたことを特徴とする磁性薄膜メモリ素子。

【請求項４】　請求項１記載の磁性薄膜メモリ素子に於いて、絶縁層の材料としてアルミニウムを含有する酸化物を用いたことを特徴とする磁性薄膜メモリ素子。

【請求項５】　請求項１乃至４記載のいずれかの磁性薄膜メモリ素子が、マトリックス状に配列された記憶素子部分と、縦又は横方向に並べられた前記磁性薄膜素子が、直列に接続された読み出し線と、該読み出し線に平行な方向と垂直な方向に絶縁材を介して設けられた２本の書き込み線を有することを特徴とする磁性薄膜メモリ。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は磁化方向の違いによって情報を記憶する磁性薄膜メモリにかかり、特に、磁気記録された情報を磁気トンネリング効果により再生する磁性薄膜メモリに関する。

【０００２】

【従来の技術】現在、情報処理装置に使用されている不揮発性メモリとしては、フラッシュＥＥＰＲＯＭやハードディスク装置などがある。これら不揮発性メモリに於いては、情報処理装置の高速化に伴い、書き込み時間及び読み出し時間の短くすることが、重要な課題になっている。

【０００３】かかる、不揮発性メモリの高速化に有効な技術として、巨大磁気抵抗効果（ＧＭＲ）を利用した磁性薄膜メモリ素子が知られている。この巨大磁気抵抗効果は、異方性磁気抵抗効果（ＡＭＲ）を上回る磁気抵抗変化率を示すものであり、ＡＭＲと異なり、抵抗値は電流と磁界の角度に依存せず、磁化容易軸が平行な２つの磁性層の磁化方向が同一方向の場合、抵抗値が最小になり、逆方向（１８０°逆方向）の場合、最大になる現象である。

【０００４】上記巨大磁気抵抗効果を利用した不揮発性メモリでは、非磁性層を挟んで対向する２つの磁性層の磁化方向により、情報を記憶する。かかる、巨大磁気抵抗効果を利用した不揮発性メモリとしては、弱い磁界を加えるだけで磁化方向が変化する磁性層に情報を書き込むスピンバルブ型と、強い磁界を加えなければ磁化方向が変化しない磁性層に情報を書き込む誘導フェリ型がある。

【０００５】［スピンバルブ型について］弱い磁界を加えるだけで磁化方向が変化する磁性層に情報を記憶するものとして、スピンバルブといわれるものがある。スピンバルブは磁化方向が固定された磁性層（以下、ピン層という）と、外部磁界で磁化方向が自由に変化する磁性層（以下、フリー層という）を組み合わせた多層膜であり、ピン層とフリーの磁化方向が同一方向の場合と逆方向の場合で抵抗値が異なるという特性を有する。例えば、Phys. Rev. B, 43, 1297 (1991) には、磁性層ＮｉＦｅ／非磁性層Ｃｕ／磁性層ＮｉＦｅ／反強磁性層ＦｅＭｎを積層した磁性薄膜の例が示されている。この磁性薄膜に於いては、反強磁性層に隣接した磁性層（ピン層）の磁化方向はＮｉＦｅ／ＦｅＭｎ界面での交換異方性により固定され、他方の磁性層（フリー層）の磁化方向は適当な外部磁界を加えることにより自由に変えることができる。従って、外部磁界を加えてフリー層の磁化方向だけを変えれば、２つの磁性層の磁化方向を同一方向又は逆方向にすることができる。

【０００６】このスピンバルブ膜を利用した磁性薄膜メモリ素子として、USP-5, 343, 422に示されたものが知られている。この磁性薄膜メモリ素子では、２値の「０」、「１」を、２つの磁性層の磁化方向が同一方向又は逆方向という２つの状態として書き込み、両状態に於ける抵抗値の差異を検出することにより、書き込まれた情報を読み出している。このタイプの場合、上記両状態に於ける抵抗値の差異を読み出す際に、磁性薄膜メモリ素子に電流を流すと共に、外部磁界を加える必要があり、この外部磁界により、書き込まれていた情報（フリー層の磁化方向）が読み出した後に変化することがあり、非破壊で書き込まれている情報を読み出すことが難しかった。

【０００７】［誘導フェリ型について］Jpn. J. Appl. Phys. 33 (1994) L1668には、ＣｏＰｔからなる保磁力の高い硬磁性層（ハード層）とＮｉＦｅＣｏからなる軟磁性層（ソフト層）を非磁性層Ｃｕを介して積層した誘導フェリ型の磁性薄膜の例が示されている。この磁性薄膜では、ハード層とソフト層の磁化方向が同一方向の場合と逆方向の場合に、その抵抗値が変化する。

【０００８】この磁性薄膜を利用した磁性薄膜メモリ素子として、Jpn. J. Appl. Phys. Part2, 34 (1994) L415に示されたものが知られている。この磁性薄膜メモリ素子では、ハード層に情報を書き込むため、書き込まれている情報を破壊することなく読み出すことができる。

【０００９】ここで、この磁性薄膜メモリ素子に情報を書き込む場合と読み出す場合について、図１２から図１４に示した薄膜断面の模式図を参照して説明する。

【００１０】図１２は、この磁性薄膜メモリ素子に、情報を書き込む場合を示す。同図に示したように、この磁

性薄膜メモリ素子は、非磁性層４３を介して積層されたソフト層（磁性層）４１とハード層（磁性層）４２からなる。又、１０は外部磁界を発生させる書き込み線であり、書き込み線１０を流れる電流により発生した外部磁界の方向に、ソフト層４１及びハード層４２は磁化される。そして、ハード層４２の２つの磁化方向に、２値の「０」、「１」が割り当てられる

図１２（ａ）の場合、反時計回りの外部磁界１０ａが発生し、その結果、ソフト層４１の磁化方向は４１ａ、ハード層４２の磁化方向は４２ａになり、（ｂ）の場合、時計回りの外部磁界１０ｂが発生し、その結果、ソフト層４１の磁化方向は４１ｂ、ハード層４２の磁化方向は４２ｂになる。尚、書き込みの場合は、ソフト層４１だけでなくハード層４２の磁化方向を変えるのに十分な強度の外部磁界を加える必要がある。

【００１１】図１３は、図１２（ａ）に示した反時計回りの外部磁界１０ａで書き込まれた情報を、読み出す場合を示す。通常、磁性薄膜メモリ素子に書き込まれた情報を、読み出す場合には図１３（ａ）に示したような反時計回りの弱い（ソフト層４１の磁化方向だけが変化する磁界強度）外部磁界１０ａと、（ｂ）に示したような時計回りの弱い外部磁界１０ｂが、この順で、磁性薄膜メモリ素子に加えられるように書き込み線１０に電流を流す。この際、磁性薄膜メモリ素子と接続する読み出し線5には電流Ｉｒを流しておく。

【００１２】ここで、反時計回りの弱い外部磁界１０ａを加えた場合には、ソフト層４１の磁化方向４１ａと、ハード層４２の磁化方向４２ａが同一方向になり、時計回りの弱い外部磁界１０ａを加えた場合には、ソフト層４１の磁化方向４１ｂと、ハード層４２の磁化方向４２ａが逆方向になるため、この外部磁界の変化により、磁性薄膜メモリ素子の抵抗値は、低抵抗から高抵抗に変化する。従って、外部磁界の変化時、磁性薄膜メモリ素子の出力側の電圧Ｖが降下する。

【００１３】図１４は、図8（ｂ）に示した時計回りの外部磁界１０ｂで書き込まれた情報を、読み出す場合を示す。

【００１４】ここで、（ａ）に示したような反時計回りの弱い外部磁界１０ａを加えた場合には、ソフト層４１の磁化方向４１ａと、ハード層４２の磁化方向４２ｂが逆方向になり、（ｂ）に示したような時計回りの弱い外部磁界１０ａを加えた場合には、ソフト層４１の磁化方向４１ｂと、ハード層４２の磁化方向４２ｂが同一方向になるため、この外部磁界の変化により、磁性薄膜メモリ素子の抵抗値は、高抵抗から低抵抗に変化する。従って、外部磁界の変化時、磁性薄膜メモリ素子の出力側の電圧Ｖが上昇する。

【００１５】上述のように、書き込み線１０を流れる電流を変化させるにより、磁性薄膜メモリ素子に加えられる外部磁界を変化させた場合、ハード層４２の磁化方向により、磁性薄膜メモリ素子の出力側の電圧Ｖの変動（上昇、又は降下）に差異が生じる。従って、この電圧Ｖの変動を検出することにより、ハード層４２の磁化方向として記憶されている情報を読み出すことができる。

【００１６】

【発明が解決しようとする課題】しかしながら、巨大磁気抵抗効果が得られる磁性薄膜メモリ素子は、層厚１０～２００Aの非常に薄い磁性層や、Ｃｕなどの導電性非磁性層を４層以上積層するため構造および作製プロセスが複雑になり、製造コストが高かった。

【００１７】又、通常の磁性薄膜メモリでは、メモリ素子がマトリックス状に配置され、縦又は横方向に並ぶメモリ素子が読み出し線により直列に接続さている。このメモリ素子の厚みは数百Aと非常に薄く、その抵抗値が高いため、磁性薄膜メモリを構成し、読み出し線に電流を流した場合、発熱及び発熱によるパワー損失が大きくなる。従って、素子数を多くしてメモリの容量を大きくすることが難しかった。

【００１８】そこで、本発明は、かかる従来の実情に鑑みて提案されたものであって、構造が単純な３層構造からなり、低抵抗でパワーロスが少なく、大容量化が可能な磁性薄膜メモリ素子および磁性薄膜メモリを提供することを目的とするものである。

【００１９】

【課題を解決するための手段】本発明にかかる磁性薄膜メモリ素子は、絶縁層を挟んで積層された、磁化容易軸が平行な第１磁性層及び第２磁性層を有し、該第２磁性層の保磁力は、該第１磁性層の保磁力より大きく、該第１磁性層と該第２磁性層との間で、トンネル効果が得られる部分があることを特徴とするものである。

【００２０】又、本発明にかかる磁性薄膜メモリ素子は、上記第１磁性層及び第２磁性層に挟まれた絶縁層の材料としてダイヤモンドライクカーボンを用いたことを特徴とするものである。

【００２１】又、本発明にかかる磁性薄膜メモリ素子は、上記第１磁性層及び第２磁性層に挟まれた絶縁層の材料としてポリパラキシレンを用いたことを特徴とするものである。

【００２２】又、本発明にかかる磁性薄膜メモリ素子は、上記第１磁性層及び第２磁性層に挟まれた絶縁層の材料としてアルミニウムを含有する酸化物を用いたことを特徴とするものである。

【００２３】又、本発明にかかる磁性薄膜メモリは、上記いずれかの磁性薄膜メモリ素子が、マトリックス状に配列された記憶素子部分と、縦又は横方向に並べられた前記磁性薄膜素子が、直列に接続された読み出し線と、該読み出し線に平行な方向と垂直な方向に絶縁材を介して設けられた２本の書き込み線を有することを特徴とするものである。

【００２４】

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【作用】本発明にかかる磁性薄膜メモリ素子によれば、単純な３層構造により、大きな磁気抵抗変化率（ＭＲ変化率）を得ることができる。

【００２５】又、トンネル効果によって絶縁層を流れる電流は、絶縁層の層面に垂直な方向に流れるので、磁性薄膜メモリ素子の抵抗を小さくすることができる。

【００２６】又、絶縁層の材料として、ダイアモンドライクカーボン、ポリパラキシリレン又はアルミニウムを主成分とする酸化物を用いた場合には、トンネル効果の得られるトンネル接合を容易に形成することができる。

【００２７】又、本発明にかかる磁性薄膜メモリ素子を用いた磁性薄膜メモリによれば、メモリ素子が単純な３層構造であるため、単純な製造工程で、磁性薄膜メモリを製造することができる。

【００２８】又、本発明にかかる磁性薄膜メモリ素子を用いた磁性薄膜メモリによれば、素子の抵抗が小さく、磁界を印加しない状態では、素子が低抵抗状態になるので、メモリの大容量化が可能になると共に、低消費電力の磁性薄膜メモリを提供することができる。

【００２９】

【実施例】

［本発明にかかる磁性薄膜メモリ素子の構成について］

本発明に係る磁性薄膜メモリ素子は、第１磁性層と第２磁性層を、絶縁層を介してトンネル接合した３層構造を有し、上記第１磁性層と第２磁性層間に現れる磁気トンネリング効果を利用したものである。一般に、金属や半導体を薄い絶縁層で隔ててポテンシャルバリアを作っても、伝導電子はトンネル効果によりある程度絶縁層を通過する。又、強磁性体金属の電子状態はスピンに依存しているため、上記第１磁性層と第２磁性層間に現れるトンネル効果は、これらの磁性層の磁化方向の相対角度に依存することが知られている（Ｊ．Ｍａｇｎ．Ｍａｇｎ．Ｍａｔｅｒ．９８（１９９１）Ｌ７－Ｌ９）。そして、このようなトンネル接合された部分に於ける磁気抵抗効果を、磁気トンネリング効果という。

【００３０】又、上記磁気トンネリング効果に寄与する、第１磁性層と第２磁性層の磁化容易軸は平行で、第２磁性層の保磁力は第１磁性層の保磁力より大きい。従って、第１磁性層及び第２磁性層に加える外部磁界の強度を調整することにより、第１磁性層のみ、又は第１磁性層と第２磁性層の双方の磁化方向を変えることができる。

【００３１】そして、上記磁気トンネリング効果により第１磁性層と第２磁性層の磁化方向が、同一方向のときに電気抵抗が低くなり、逆方向（１８０°逆方向）のときに高くなる。従って、外部磁界により第１磁性層のみの磁化方向を一定の順序で変化させた場合（例えば、磁化方向を左方向から右方向に変えた場合）、第２磁性層の磁化方向に応じて、電気抵抗が、低抵抗から高抵抗に、又は高抵抗から低抵抗に変化する。

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【００３２】ここで、第１磁性層はできるだけ弱い外部磁界で磁化方向が変化する必要があるため、保磁力は小さい方がよく、好ましくは５０［Oe］以下、より好ましくは１０［Oe］以下である。ここで保磁力の範囲を５０［Oe］以下としたのは、５０［Oe］より大きいと磁化方向を変えるときに、強い外部磁界を発生させる電流が必要になるため、磁性薄膜メモリを構成したときに発熱やノイズが増加し、誤動作をすることがあるからである。尚、磁性層の保磁力の大きさは、組成、層厚や成膜条件を調整することにより所定の大きさに設定することができるが、層厚は、５～１００nmであることが好ましい。５nmより薄いと膜がアイランド状になるため、電気抵抗が高くなり好ましくないからである。又、第１磁性層の材料としては、Ｆｅ、ＮｉＦｅ、ＮｉＦｅＣｏ等を用いることができる。

【００３３】一方、第２磁性層の保磁力は、第１磁性層の保磁力より大きくする必要があり、好ましくは５０［Oe］以上、より好ましくは１００［Oe］以上である。ここで保磁力の範囲を５０［Oe］以上としたのは、５０［Oe］より小さいと、磁化方向が外部擾乱磁界などの影響で乱され、メモリが破壊されてしまうことがあるからである。尚、第２磁性層の保磁力の大きさも、第１磁性層と同様に、組成、層厚や成膜条件を調整することにより所定の大きさに設定することができ、層厚については、５～１００nmであることが好ましい。又、第２磁性層の材料としては、Ｃｏ、ＣｏＦｅ、ＣｏＰｔ、ＭｎＳｂ等を用いることができる。

【００３４】上記第１磁性層と第２磁性層の保磁力の差は２０［Oe］以上は必要で、好ましくは５０［Oe］以上、より好ましくは１００［Oe］以上である。ここで保磁力の差を２０［Oe］以上としたのは、保磁力の差が２０［Oe］より小さいと、情報を読み出すときに、第１磁性層の磁化方向だけを変化させるために加える外部磁界の許容変動範囲、つまり、この外部磁界を発生させるための電流の許容変動範囲が小さくなるからである。

【００３５】又、上記磁気トンネリング効果を得るためには、上記第１磁性層と第２磁性層に挟まれた絶縁層の層厚は、均一に薄くする必要があり、好ましくは１～２０nm、より好ましくは１～１０nmの範囲である。ここで、絶縁層の層厚の範囲を１～２０nmとしたのは、１nmより薄いとピンホールが多くなり均一なポテンシャルバリアが形成されず、２０nmより厚いとトンネリング効果が起こらなくなるからである。従って、絶縁層の材料としては、薄い層厚でもピンホールなどの発生が少ない材料が必要とされ、これに適した材料としては、ダイアモンドライクカーボン（以下、ＤＬＣという）、ポリパラキシリレン、アルミニウムを主成分とする酸化物が挙げられるが、ＤＬＣ、又はポリパラキシリレンを用いることが好ましい。

【００３６】［本発明にかかる磁性薄膜メモリ素子の動

作原理について］本発明にかかる磁性薄膜メモリ素子に情報を書き込む場合と、磁性薄膜メモリ素子から読み出す場合について、図１から図３に示した薄膜断面の模式図を参照して説明する。

【００３７】図１は、この磁性薄膜メモリ素子に、情報を書き込む場合を示す。同図に示したように、この磁性薄膜メモリ素子は、絶縁層３を介して積層された第１磁性層１と第２磁性層２からなる。又、１０は外部磁界を発生させる書き込み線であり、書き込み線１０を流れる電流により発生した外部磁界の方向に、第１磁性層１及び第２磁性層２は磁化される。そして、第２磁性層２の磁化方向に、２値の「０」、「１」が割り当てられる。

【００３８】図１（ａ）の場合、書き込み線１０を流れる電流により、反時計回りの外部磁界１０ａが発生し、その結果、第１磁性層１の磁化方向は１ａ、第２磁性層２の磁化方向は２ａになり、（ｂ）の場合、時計回りの外部磁界１０ｂが発生し、その結果、第１磁性層１の磁化方向は１ｂ、第２磁性層２の磁化方向は２ｂになる。尚、書き込みの場合は、第１磁性層１だけでなく第２磁性層２の磁化方向を変えるのに十分な強度の外部磁界を加える必要がある。

【００３９】図２は、図１（ａ）に示した反時計回りの外部磁界１０ａで書き込まれた情報を、読み出す場合を示す。通常、磁性薄膜メモリ素子に書き込まれた情報を、読み出す場合には図２（ａ）に示したような反時計回りの弱い（第１磁性層１の磁化方向だけが変化する磁界強度）外部磁界１０ａと、（ｂ）に示したような時計回りの弱い外部磁界１０ｂが、この順で、磁性薄膜メモリ素子に加えられるように書き込み線１０に電流を流す。この際、磁性薄膜メモリ素子と接続する読み出し線５には電流Ｉｒを流しておく。

【００４０】ここで、反時計回りの弱い外部磁界１０ａを加えた場合には、第１磁性層１の磁化方向１ａと、第２磁性層２の磁化方向２ａが同一方向になり、時計回りの弱い外部磁界１０ａを加えた場合には、第１磁性層１の磁化方向１ｂと、第２磁性層２の磁化方向２ａが逆方向になるため、この外部磁界の変化により、磁性薄膜メモリ素子の抵抗値は、低抵抗から高抵抗に変化する。従って、外部磁界の変化時、つまり、書き込み線１０を流れる電流を変化させたときに、磁性薄膜メモリ素子の出力側の電圧Ｖが降下する。

【００４１】図３は、図１（ｂ）に示した時計回りの外部磁界１０ｂで書き込まれた情報を、読み出す場合を示す。

【００４２】ここで、反時計回りの弱い外部磁界１０ａを加えた場合には、第１磁性層１の磁化方向１ａと、第２磁性層２の磁化方向２ｂが逆方向になり、時計回りの弱い外部磁界１０ａを加えた場合には、第１磁性層１の磁化方向１ｂと、第２磁性層２の磁化方向２ｂが同一方向になるため、この外部磁界の変化により、磁性薄膜メモリ素子の抵抗値は、高抵抗から低抵抗に変化する。従って、外部磁界の変化時、磁性薄膜メモリ素子の出力側の電圧Ｖが上昇する。

【００４３】上述のように、書き込み線１０を流れる電流を変化させるにより、磁性薄膜メモリ素子に加えられる外部磁界を変化させた場合、第２磁性層２の磁化方向により、磁性薄膜メモリ素子の出力側の電圧Ｖの変動に差異が生じる。

【００４４】尚、外部磁界を取り去ったときに、第１磁性層の磁化方向と第２磁性層の磁化方向が異なる場合は、第１磁性層の磁化方向は、第１磁性層より保磁力の大きい第２磁性層の磁化方向と同一の方向に戻る。従って、マトリックス状に磁性薄膜メモリ素子を配列して磁性薄膜メモリを構成した場合に、外部磁界を加えていない素子は、全て低抵抗になるため、発熱及び発熱によるパワー損失を小さくすることができる。

【００４５】図４（ａ）は、情報を読み出すときに、書き込み線を流れる＋側から－側に変化する電流（以下、再生パルス電流という）を、（ｂ）、（ｃ）は、（ａ）に示した再生パルス電流を流したときの磁性薄膜メモリ素子の出力側の電圧Ｖの変動を示す。ここで、同図の（ａ）に示したように、書き込み線を流れる電流が＋側から－側に変化したとき、磁性薄膜メモリ素子に加えられる外部磁界が変化する。つまり、＋側のとき、図２、３に示した反時計回りの磁界が発生し、－側のとき、図２、３に示した反時計回りの磁界が発生する。そして、この変化時に磁性薄膜メモリ素子の出力側の電圧Ｖは、第２磁性層の磁化方向に応じて、（ｂ）に示したように上昇するか、又は（ｃ）に示したように降下する。従って、情報を読み出すときには、書き込み線に再生パルス電流を流し、そのときに磁性薄膜メモリ素子の出力側と接続する読み出し線に生じる電圧変動を検出することにより、第２磁性層の磁化方向を判断することができる。

【００４６】又、情報を読み出すときに、図４（ｄ）に示したような＋側の電流だけを流しても第２磁性層の磁化方向を判断することができる。この場合、情報を読み出すときに、磁性薄膜メモリ素子には、＋側の電流による磁界（図２、３に示した反時計回りの磁界）だけが印加される。そして、この電流を流したときに磁性薄膜メモリ素子の出力側の電圧Ｖは、第２磁性層の磁化方向に応じて、（ｅ）に示したように変動しないか、又は（ｃ）に示したように変動する（低下する）。従って、電流を流したときに電圧変動が生じるか否かを検出することにより、第２磁性層の磁化方向を判断することができる。

【００４７】尚、第２磁性層の２つの磁化方向は、２値の「０」、「１」に割り当てられているため、第２磁性層の磁化方向の設定は、磁性薄膜メモリ素子への情報の書き込みに対応し、第２磁性層の磁化方向の検出は、磁性薄膜メモリ素子からの情報の読み出しに対応する。

【００４８】［本発明にかかる磁性薄膜メモリについて］本発明にかかる磁性薄膜メモリについて、図５から図８を参照して説明する。

【００４９】図５は、磁性薄膜メモリに於ける１素子部分の平面図（ａ）とそのＡＡ’断面図（ｂ）を示し、読み出し線５と接続する第１磁性層１と第２磁性層２が、絶縁層３を介して積層されている。ここで、第１磁性層１と第２磁性層２はトンネル接合されていて、第１磁性層１と第２磁性層２が重なり合った部分がトンネル接合部になる。又、第２磁性層２の保磁力は、第１磁性層１の保磁力より大きくしてある。

【００５０】尚、本発明の磁性薄膜メモリ素子に於いては、トンネル接合部を流れる読み出し電流は、矢印８に示したように絶縁層３の膜面に垂直な方向に電流が流れるため素子の抵抗が小さくなり、素子の発熱が少なくすることができる。又、サブミクロンオーダーの素子が形成可能となり、メモリを大容量化することができる。

【００５１】又、上記磁性薄膜メモリ素子の磁化容易軸４と垂直な方向に、書き込み線１０が設けられ、平行な方向に、書き込み補助線２０が設けられている。そして、上記磁性薄膜メモリ素子、書き込み線１０、書き込み補助線２０は絶縁膜７、絶縁膜６で絶縁されている。

【００５２】図６は、磁性薄膜メモリの平面図（ａ）とそのＢＢ’断面図（ｂ）を示し、書き込み線１１、１２、１３と書き込み補助線２１、２２、２３が直交する部分に、磁性薄膜メモリ素子がマトリックス状に配列されている。ここで、磁性薄膜メモリ素子は、読み出し補助線方向に直列に接続され、読み出し線を形成している。例えば、ＢＢ’断面に示した部分では、磁性薄膜メモリ素子３１、３２、３３が直列に接続された部分が、読み出し線５になる。

【００５３】このように、磁性薄膜メモリ素子がマトリックス状に配列されている場合に、書き込み線に、磁性薄膜メモリ素子の第２磁性層の磁化方向を変化させるのに十分な書き込み電流を流した場合、書き込み電流を流した書き込み線に沿って配列された磁性薄膜メモリの第１磁性層及び第２磁性層は、全て書き込み電流により発生した磁界の方向に磁化されてしまう。つまり、書き込み電流を流した書き込み線に沿って配列された磁性薄膜メモリには、全て書き込みが行われる。従って、磁性薄膜メモリ素子をマトリックス状に配列した場合には、１本の書き込み線を流れる電流だけでは、磁性薄膜メモリ素子の一部の素子の磁化方向だけを所望の磁化方向に向かせること、つまり、一部の素子だけに情報を書き込むことができない。

【００５４】ここで、書き込み線と書き込み補助線の双方に電流を流すことにより、マトリックス状に配列された磁性薄膜メモリ素子の一部の素子の磁化方向だけを所望の磁化方向に向かせる場合、つまり、一部の素子だけに情報を書き込む場合について、図７、図８を参照して説明する。

【００５５】図７（ａ）に於いて、Ｉｗ１は書き込み線１０を流れる書き込み電流を示し、Ｉｗは書き込み補助線２０を流れる書き込み補助電流を示す。そして、Ｈｗ１は、書き込み電流Ｉｗ１により発生した書き込み磁界を示し、Ｈｗは、書き込み補助電流Ｉｗにより発生した書き込み補助磁界を示す。ここで、書き込み磁界Ｈｗ１及び書き込み補助磁界Ｈｗは、共に磁性薄膜メモリ素子の第２磁性層の保磁力より小さいため、一方の磁界だけでは、第２磁性層の磁化方向を変えることができない。しかし、書き込み磁界Ｈｗ１と書き込み補助磁界Ｈｗの合成磁界Ｈ１は、第２磁性層の保磁力より大きいため、書き込み電流Ｉｗ１と書き込み補助電流Ｉｗの双方を流した場合には、第２磁性層の磁化方向を変えることができる。

【００５６】図７（ｂ）は、書き込み磁界Ｈｗ１、書き込み補助磁界Ｈｗ、合成磁界Ｈ１及び第２磁性層２の磁化容易軸４を示す。ここで、合成磁界Ｈ１は、第２磁性層２の保磁力より大きいため、第２磁性層２は、合成磁界Ｈ１により磁化され、その磁化方向Ｂ１は、合成磁界Ｈ１の磁化容易軸４に平行な成分の方向になる。尚、書き込み電流Ｉｗ１により発生する書き込み磁界Ｈｗ１は、第２磁性層２の磁化容易軸４にほぼ平行で、書き込み補助電流Ｉｗにより発生する書き込み補助磁界Ｈｗは、第２磁性層２の磁化容易軸４にほぼ垂直なので、磁化方向Ｂ１は、書き込み磁界Ｈｗ１つまり書き込み電流Ｉｗ１により決まる。

【００５７】図８（ａ）は、図７の書き込み電流Ｉｗ１と逆の方向に書き込み電流Ｉｗ２を流している。従って、発生する書き込み磁界Ｈｗ２の方向も図７の書き込み磁界Ｈｗ１と逆の方向になる。従って、（ｂ）に示したように第２磁性層の磁化方向Ｂ２も図７の磁化方向Ｂ１と逆の方向になる。

【００５８】上述のように、マトリックス状に、磁性薄膜メモリ素子を配列した場合には、磁化方向を変化させたい磁性薄膜メモリ素子の部分を通る書き込み線及び書き込み補助線だけに電流を流すことにより、その部分の磁性薄膜メモリ素子の磁化方向だけを変えることができる。又、磁性薄膜メモリ素子の磁化方向は、書き込み線を流れる電流の方向により、所望の方向に向けることができる。

【００５９】一方、マトリックス状に配列された磁性薄膜メモリ素子に、書き込まれた情報を読み出す場合には、読み出したい磁性薄膜メモリ素子が接続された読み出し線に読み出し電流を流すと共に、その磁性薄膜メモリ素子の部分を通る書き込み線に再生パルス電流を流し、再生パルス電流を流したときの、読み出し線の電圧変動を検出することにより、書き込まれた情報である第２磁性層の磁化方向を判別することができる。

【００６０】（実施例１）保磁力の小さい第１磁性層１

としてＦｅ、保磁力の大きい第２磁性層２としてＣｏ、絶縁層３としてＤＬＣを用い、Ｆｅ（５０nm）／ＤＬＣ（２nm）／Ｃｏ（５０nm）の強磁性トンネル接合と磁性薄膜メモリ素子を作製した。図９は、強磁性トンネル接合９の磁気抵抗曲線を調べるために作製した試料の斜視図（ａ）と平面模式図（ｂ）を示す。尚、磁気抵抗曲線は直流４端子法で印加磁場５００［Oe］のもとで測定した。また、１０mm角の大きさのＦｅ／ＤＬＣ／Ｃｏ３層膜も作製し、ＶＳＭで磁化曲線を調べた。

【００６１】以下に、強磁性トンネル接合を形成する工程を説明する。

【００６２】まず、ガラス基板上にＤＣスパッタ法により以下に示す成膜条件でＦｅ層を層厚５０nmで形成した。

【００６３】

到達圧力	５×１０$^{-5}$ Pa
Ａｒガス	１０ SCCM
成膜圧力	０．５ Pa
投入パワー	１００ W
成膜レート	０．５ nm／sec

こうして得られたＦｅ層を、微細加工技術を用いて１mm×１０mmの長方形にパターニングし、第１磁性層１とした。

【００６４】次に、第１磁性層１の上にプラズマＣＶＤ法により以下に示す成膜条件でＤＬＣ膜を膜厚２nmで形成した。

【００６５】

到達圧力	３×１０$^{-3}$ Pa
エチレンガス	１０ SCCM
成膜圧力	３ Pa
投入パワー	１００ W
成膜レート	１０ nm／min

こうして得られたＤＬＣ膜を、φ３mmに微細加工し、絶縁層３とした。

【００６６】続いて、これを再度ＤＣスパッタ装置に移し、以下の成膜条件でＣｏ層を層厚５０nmで形成した。

【００６７】

到達圧力	５×１０$^{-5}$ Pa
Ａｒガス	１０ SCCM
成膜圧力	０．５ Pa
投入パワー	１００ W
成膜レート	０．５ nm／sec

こうして得られたＣｏ層を、第１磁性層と同様に微細加工技術により１mm×１０mmのストライプ状にパターニングし、接合面積が１mm×１mmのＦｅ／ＤＬＣ／Ｃｏの強磁性トンネル接合９を形成し、磁気抵抗曲線を調べた。

【００６８】又、同様の方法で１０mm×１０mmのトンネル接合を形成し、磁化曲線も調べた。その結果、図１０に示した磁気抵抗曲線と、図１１に示したＶＳＭによる磁化曲線が得られた。ここで、図１０に示したＭＲ変化率は（ΔＲ／Ｒ）×１００（Ｒ：抵抗値、ΔＲ：抵抗値の変化量）で与えられ、本実施例の試料では、印加磁場１００［Oe］以下で１２％のＭＲ変化率が得られた。

【００６９】このＦｅ／ＤＬＣ／Ｃｏ強磁性トンネル接合を用いて図５に示したような磁性薄膜メモリ素子を、以下のよう工程で作製した。

【００７０】まず、ガラス基板上の読み出し線を形成する方向に５００［Oe］の磁場を印加しながらＦｅ層を層厚５０nmで形成した後、微細加工技術を用いて２μm×１０μmの長方形にパターニングし、第１磁性層１とした。このように、磁場を印加しながら成膜することにより、形成された磁性層の磁化容易軸が、印加した磁場の方向に平行になる。

【００７１】次に、第１磁性層１の上にダイアモンドライクカーボン（ＤＬＣ）膜を膜厚２nm形成し、微細加工し、絶縁層３とした。

【００７２】続いて、再度これをＤＣスパッタ装置に移し、Ｆｅ層の場合と同様の磁場を印加しながら、Ｃｏ層を層厚５０nmで形成した後、微細加工技術により１μm×１０μmのストライプ状にパターニングし、第２磁性層２とした。以上の工程により接合面積が１μm×３μmのＦｅ／ＤＬＣ／Ｃｏのトンネル接合を形成した。

【００７３】次に、第１磁性層１及び第２磁性層２に接続するようにＣｒ（５nm）／Ａｕ（２００nm）／Ｃｒ（５nm）膜を読み出し線５として形成した。

【００７４】続いて、アルミナからなる絶縁膜７をＲＦスパッタ法で膜厚２００nm形成した後、再度Ｃｒ（５nm）／Ａｕ（２００nm）／Ｃｒ（５nm）膜を成膜し、トンネル接合部の上部に読み出し線５と平行な方向に帯状にパターニングして書き込み補助線２０を形成した。更に、同様な方法で、膜厚２００nmのアルミナからなる絶縁膜６と書き込み補助線２０と直角する方向に帯状にパターニングされた書き込み線１０を形成し、磁性薄膜メモリ素子とした。

【００７５】こうして得られた磁性薄膜メモリの動作確認を行ったところ、書き込みと読み出しを正常に行うことができた。つまり、書き込み時には、書き込み電流によって発生した磁界の方向に、磁性薄膜メモリ素子の第１磁性層１及び第２磁性層２が磁化し、読み出し時には、再生パルス電流を流すことにより、読み出し線から所望の電圧変動を得ることができた。

【００７６】（実施例２）実施例１と同様の方法で、表１に記載の膜構成の強磁性トンネル接合を作製し、磁気抵抗曲線を調べ、得られた磁気抵抗変化率を表１に示した。同表に示したように、いずれの試料についても５～２５％のＭＲ変化率が得られることを確認できた。

【００７７】次に、これらの強磁性トンネル接合を用いた磁性薄膜メモリ素子を作製し、実施例１と同様に動作確認を行ったところ、書き込みと読み出しを正常に行うことができた。

【００７８】比較試料についても同様の方法で、表１に記載の膜構成でダイアモンドライクカーボン膜を絶縁層とした強磁性トンネル接合を作製し、磁気抵抗曲線を調べ、得られた磁気抵抗変化率を表１に示した。同表に示したように、いずれの比較試料も０．１～０．２％のＭＲ変化率しか得られなかった。この理由としては、絶縁層厚が１nmと薄い場合は均一な絶縁層が形成されないためピンホールが多くなり、２つの磁性層間で電気的なブリッジが形成されてしまうためと考えられる。また、絶縁層厚が３０nmと厚い場合はトンネル電流が散乱されてしまうためと考えられる。

【００７９】次に、比較試料の強磁性トンネル接合を用いた磁性薄膜メモリ素子を作製し、上記試料と同様に動作確認を行ったところ、正常に動作しなかった。

【００８０】

【表１】

サンプル	第1磁性層	第1磁性層厚 (nm)	第2磁性層	第2磁性層厚 (nm)	絶縁層	絶縁層厚 (nm)	MR変化率 (%)
試料1	Fe	50	Co	50	DLC	2	12
試料2	$Ni_{80}Fe_{20}$	10	Co	20	DLC	5	5
試料3	$Fe_{50}Co_{50}$	80	Co	5	DLC	3	15
試料4	$Ni_{80}Fe_{20}$	5	$Fe_{50}Co_{50}$	10	DLC	10	7
試料5	Fe	50	$Fe_{50}Co_{50}$	50	DLC	6	28
比較試料1	Fe	5	Co	5	DLC	1	0.2
比較試料2	$Ni_{80}Fe_{20}$	10	Co	20	DLC	30	0.1

【００８１】（実施例３）実施例１と同様の方法で、表２に記載の膜構成で、ポリパラキシリレンを絶縁層とした強磁性トンネル接合を作製し、磁気抵抗曲線を調べ、得られた磁気抵抗変化率を表２に示した。同表に示したように、いずれの試料についても６～１３％のＭＲ変化率が得られることが確認できた。

【００８２】尚、ここでは、ポリパラキシリレン膜は以下の方法で作製した。まず、原料のジパラキシリレンを真空下で約１５０℃で気化したのち、炉の中で６００℃で熱分解し、成膜室で反応圧力２０mTorrでポリパラキシリレン膜を作製した。ポリパラキシリレンとしてユニオンカーバイド社のパリレンＮおよびパリレンＣを、成膜速度は１０nm/minで成膜した。

【００８３】次に、これらの強磁性トンネル接合を用いた磁性薄膜メモリ素子を作製し、実施例１と同様に動作確認を行ったところ、書き込みと読み出しを正常に行うことができた。

【００８４】比較試料についても同様の方法で、表２に記載の膜構成でポリパラキシリレンまたはポロモノクロパラキシリレンを絶縁層とした強磁性トンネル接合を作製し、磁気抵抗曲線を調べ、得られた磁気抵抗変化率を表２に示した。同表に示したように、いずれの比較試料も０．１～０．３％のＭＲ変化率しか得られなかった。この理由としては、絶縁層厚が１nmと薄い場合は均一な絶縁層が形成されないためピンホールが多くなり、２つの磁性層間で電気的なブリッジが形成されてしまうためと考えられる。また、絶縁層厚が２５nmと厚い場合はトンネル電流が散乱されてしまうためと考えられる。

【００８５】次に、比較試料の強磁性トンネル接合を用いた磁性薄膜メモリ素子を作製し、上記試料と同様に動作確認を行ったところ、正常に動作しなかった。

【００８６】

【表２】

サンプル	第1磁性層	第1磁性層厚 (nm)	第2磁性層	第2磁性層厚 (nm)	絶縁層	絶縁層厚 (nm)	MR変化率 (%)
試料6	$Fe_{50}Co_{50}$	20	Co	30	ﾊﾟﾘﾚﾝN	15	13
試料7	$Ni_{66}Fe_{16}Co_{18}$	10	$Fe_{50}Co_{50}$	10	ﾊﾟﾘﾚﾝN	7	9
試料8	$Ni_{80}Fe_{20}$	20	$Fe_{50}Co_{50}$	20	ﾊﾟﾘﾚﾝC	10	6
試料9	$Ni_{66}Fe_{16}Co_{18}$	10	Co	30	ﾊﾟﾘﾚﾝC	7	7
比較試料3	$Fe_{50}Co_{50}$	20	Co	30	ﾊﾟﾘﾚﾝN	25	0.3
比較試料4	$Ni_{66}Fe_{16}Co_{18}$	10	Co	30	ﾊﾟﾘﾚﾝC	1	0.1

【００８７】（実施例４）実施例１と同様の方法で、表３に記載の膜構成で、Al_2O_3を絶縁層とした強磁性トンネル接合を作製し、磁気抵抗曲線を調べ、得られた磁気抵抗変化率を表３に示した。同表に示したように、いずれの試料についても１３～２０％のＭＲ変化率が得られることが確認できた。

【００８８】尚、ここでは、Al_2O_3絶縁層はＡｌ金属膜をスパッタ法で作製したのち、大気中で２４時間自然酸化させ、形成した。

【００８９】次に、これらの強磁性トンネル接合を用いた磁性薄膜メモリ素子を作製し、実施例１と同様に動作確認を行ったところ、書き込みと読み出しを正常に行うことができた。

【００９０】比較試料についても同様の方法で、表３に記載の膜構成でAl_2O_3を絶縁層とした強磁性トンネル接合を作製し、磁気抵抗曲線を調べ、得られた磁気抵抗

抗変化率を表３に示した。同表に示したように、比較試料では０．２％のＭＲ変化率しか得られなかった。この理由としては、絶縁層が１nmと薄いためピンホールが多くなり、上下の磁性層間で電気的にブリッジができるためと考えられる。

【００９１】次に、比較試料の強磁性トンネル接合を用いた磁性薄膜メモリ素子を作製し、上記試料と同様に動作確認を行ったところ、正常に動作しなかった。

【００９２】

【表３】

サンプル	第1磁性層	第1磁性層厚 (nm)	第2磁性層	第2磁性層厚 (nm)	絶縁層	絶縁層厚 (nm)	MR変化率 (%)
試料10	$Fe_{50}Co_{50}$	20	Co	40	Al_2O_3	3	13
試料11	$Fe_{50}Co_{50}$	50	Fe	40	Al_2O_3	3	20
比較試料5	$Fe_{50}Co_{50}$	20	Co	40	Al_2O_3	1	0.2

【００９３】又、実施例１～３で作製した磁性薄膜メモリ素子の抵抗を調べた結果、１～５Ωと非常に低かった。この値は同じ大きさのスピンバルブ構造ＧＭＲメモリ素子の抵抗の１／１０以下と低い。

【００９４】以上から明瞭なように、本発明によれば、非常に単純な、磁性層／絶縁層／磁性層の３層構造を有し、かつ低抵抗な磁性薄膜メモリ素子を提供することができる。

【００９５】

【発明の効果】本発明にかかる磁性薄膜メモリ素子は、以上で説明したように、単純な３層構造で大きなＭＲ変化率を得ることができるため、低コストで磁性薄膜メモリ素子を形成することができる。

【００９６】又、磁性薄膜メモリ素子の抵抗を小さくし、素子に於ける発熱を少なくすることができる。

【００９７】又、絶縁層の材料として、ダイアモンドライクカーボン、ポリパラキシリレン又はアルミニウムを主成分とする酸化物を用いた場合には、トンネル効果の得られるトンネル接合を容易に形成することができる。

【００９８】又、非常に薄い磁性層や導電非磁性層等を形成することなく、単純な製造工程だけで、磁性薄膜メモリを製造することができるので、製造歩留を向上させることができる。

【００９９】又、本発明にかかる磁性薄膜メモリ素子は抵抗が小さく、磁界を印加しない状態では、低抵抗状態になるので、メモリの大容量化が可能になると共に、低消費電力の磁性薄膜メモリを提供することができる。

【図面の簡単な説明】

【図１】本発明にかかる磁性薄膜メモリ素子に対する書き込み操作を説明するための断面図である。

【図２】本発明にかかる磁性薄膜メモリ素子に対する読み出し操作を説明するための断面図である。

【図３】本発明にかかる磁性薄膜メモリ素子に対する読み出し操作を説明するための断面図である。

【図４】再生パルス電流の電流波形と再生パルス電流により読み出し線に生じる電圧変動を示した波形図である。

【図５】本発明にかかる磁性薄膜メモリ素子の構造を示した、平面図と断面図である。

【図６】本発明にかかる磁性薄膜メモリの構成を示した、平面図と断面図である。

【図７】本発明にかかる磁性薄膜メモリを構成する素子に対する書き込み操作を説明するための説明図である。

【図８】本発明にかかる磁性薄膜メモリを構成する素子に対する書き込み操作を説明するための説明図である。

【図９】トンネル接合の試料を示した斜視図と平面図である。

【図１０】実施例１のトンネル接合に於ける磁気抵抗曲線を示したグラフである。

【図１１】実施例１のトンネル接合に於ける磁化曲線を示したグラフである。

【図１２】従来の磁性薄膜メモリ素子に対する書き込み操作を説明するための断面図である。

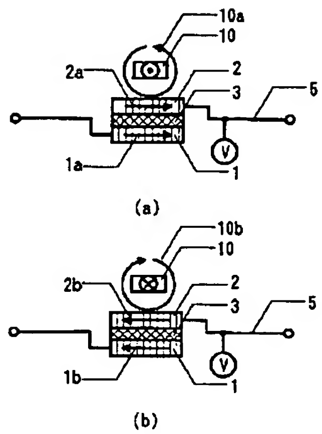
【図１３】従来の磁性薄膜メモリ素子に対する読み出し操作を説明するための断面図である。

【図１４】従来の磁性薄膜メモリ素子に対する読み出し操作を説明するための断面図である。

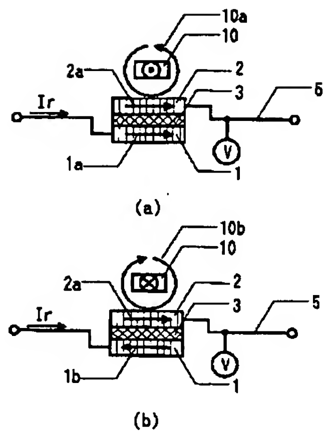
【符号の説明】

１　第１磁性層
２　第２磁性層
３　絶縁層
４　磁化容易軸
５　読み出し線
６、７　絶縁膜
１０、１１、１２、１３　書き込み線
２０、２１、２２、２３　書き込み補助線

【図１】



【図２】



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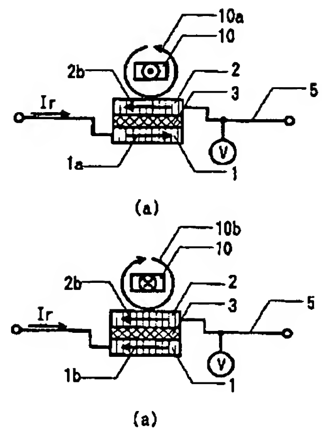

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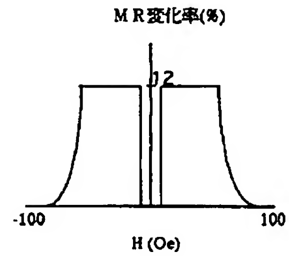

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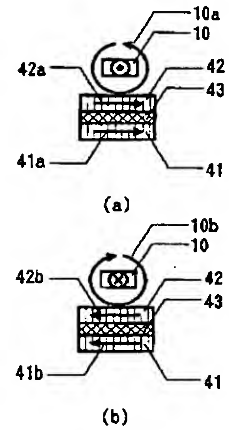

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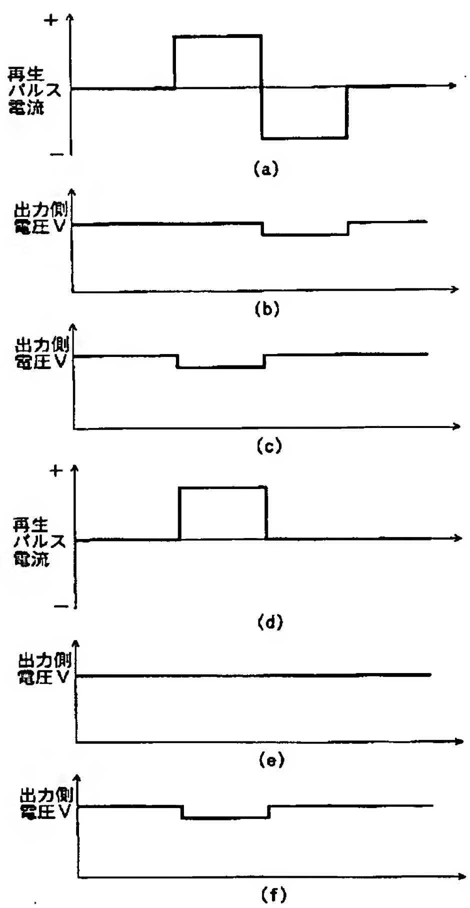

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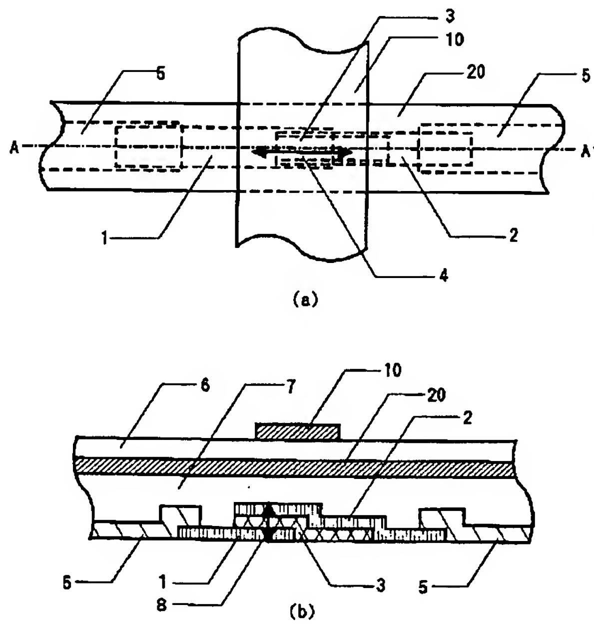

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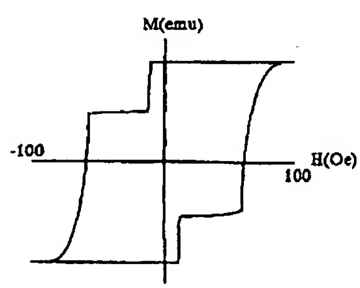

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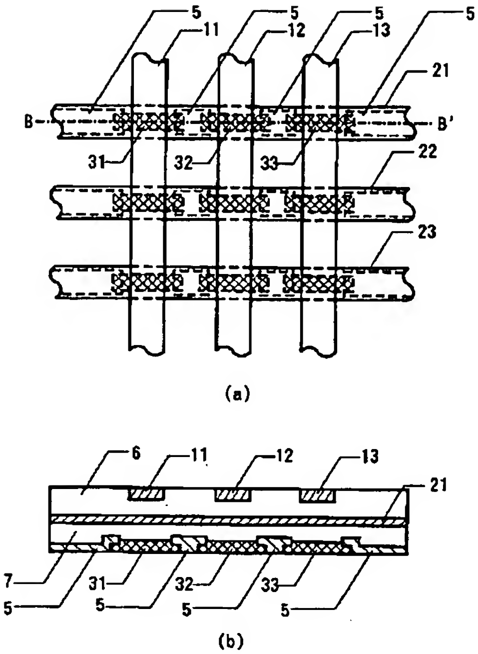

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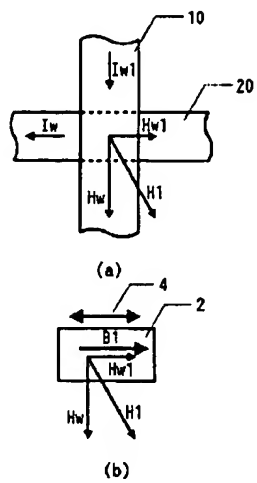

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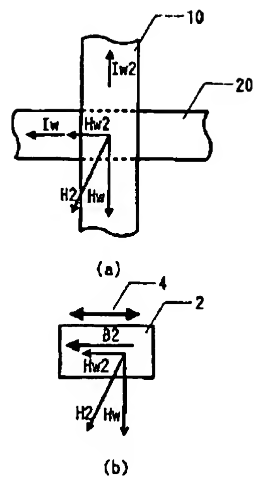

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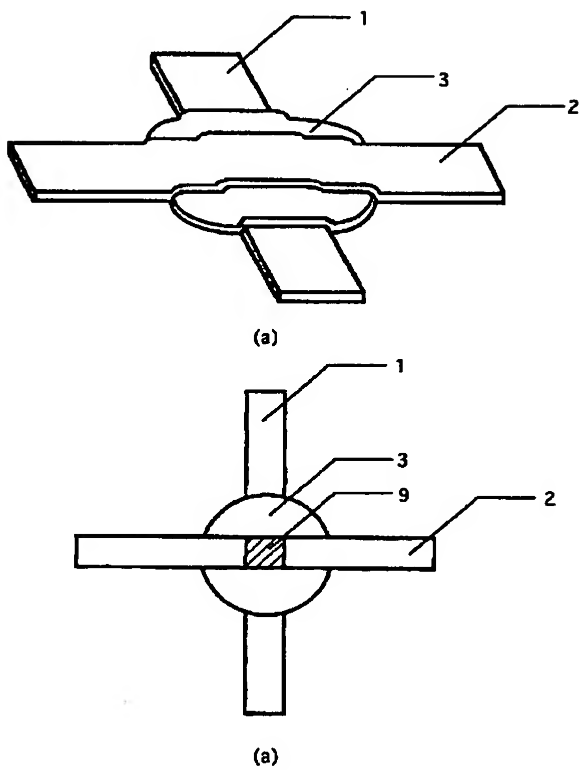

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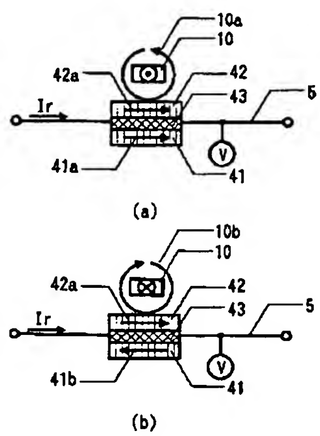

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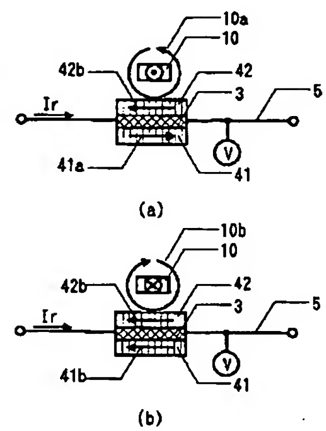

フロントページの続き

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CLAIMS

[Claim(s)]
[Claim 1] It is the magnetic-thin-film memory device which has the 1st magnetic layer and the 2nd magnetic layer with an parallel easy axis by which the laminating was carried out on both sides of the insulating layer, and is characterized by the coercive force of this 2nd magnetic layer having the part from which it is larger than the coercive force of this 1st magnetic layer, and the tunnel effect is acquired between this 1st magnetic layer and this 2nd magnetic layer.
[Claim 2] The magnetic-thin-film memory device characterized by using diamond-like carbon as an ingredient of an insulating layer in a magnetic-thin-film memory device according to claim 1.
[Claim 3] The magnetic-thin-film memory device characterized by using poly paraxylene as an ingredient of an insulating layer in a magnetic-thin-film memory device according to claim 1.
[Claim 4] The magnetic-thin-film memory device characterized by using the oxide which contains aluminum as an ingredient of an insulating layer in a magnetic-thin-film memory device according to claim 1.
[Claim 5] Magnetic-thin-film memory to which said magnetic-thin-film component compared with the storage element part in which one of magnetic-thin-film memory devices according to claim 1 to 4 was arranged in the shape of a matrix in length or a longitudinal direction is characterized by having two write-in lines which were connected to the serial, and which read and were formed in the direction perpendicular to a direction parallel to a line and this read-out line through the insulating material.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention starts the magnetic-thin-film memory which memorizes information by the difference in the magnetization direction, and relates to the magnetic-thin-film memory which reproduces the information by which magnetic recording was carried out especially according to the magnetic tunneling effectiveness.
[0002]
[Description of the Prior Art] As nonvolatile memory currently used for current and an information processor, there are a flash EEPROM, a hard disk drive unit, etc. In these nonvolatile memory, the thing of write-in time amount and read-out time amount to shorten has been an important technical problem with improvement in the speed of an information processor.
[0003] The magnetic-thin-film memory device using giant magneto-resistance (GMR) is known as a technique effective in improvement in the speed of this nonvolatile memory. It is the phenomenon which this giant magneto-resistance does not show the magnetic-reluctance rate of change exceeding an anisotropy magneto-resistive effect (AMR), it does not depend for resistance on the include angle of a current and a field unlike AMR, but resistance becomes min when the magnetization direction of two magnetic layers with an parallel easy axis is the same direction, and becomes max in the case of hard flow (180-degree hard flow).
[0004] In the nonvolatile memory using the above-mentioned giant magneto-resistance, information is memorized according to the magnetization direction of two magnetic layers which counter on both sides of a non-magnetic layer. There are a spin bulb mold which writes information in the magnetic layer from which the magnetization direction changes only by adding a weak field as nonvolatile memory using this giant magneto-resistance, and an induction ferry mold which writes information in the magnetic layer from which the magnetization direction does not change if a strong field is not added.
[0005] [Spin bulb mold] There is a thing called spin bulb to memorize information to the magnetic layer from which the magnetization direction changes only by adding a weak field. Spin bulbs are the multilayers which combined the magnetic layer (henceforth a free layer) from which the magnetization direction changes freely in the magnetic layer (henceforth a pin layer) to which the magnetization direction was fixed, and an external magnetic field, and have the property that resistance differs by the case where they are the case where a pin layer and the free magnetization direction are the same directions, and hard flow. For example, the example of the magnetic thin film which carried out the laminating of magnetic layer NiFe / non-magnetic layer Cu / magnetic layer NiFe / the antiferromagnetism layer FeMn is shown in Phys.Rev.B, and 43 and 1297 (1991). In this magnetic thin film, the exchange anisotropy in a NiFe/FeMn interface is fixed and the magnetization direction of the magnetic layer (pin layer) which adjoined the antiferromagnetism layer can change the magnetization direction of the magnetic layer (free layer) of another side freely by adding a suitable external magnetic field. Therefore, if an external magnetic field is added and only the magnetization direction of a free layer is changed, the magnetization direction of two magnetic layers can be made into the same direction or hard flow.
[0006] What was shown in USP-5,343,422 is known as a magnetic-thin-film memory device using this spin bulb film. In this magnetic-thin-film memory device, the written-in information is read by

the magnetization direction of two magnetic layers writing in binary "0" and "1" as two conditions of the same direction or hard flow, and detecting the difference in the resistance in both conditions. When reading the difference in the resistance in both the above-mentioned conditions this type of case, while passing the current to the magnetic-thin-film memory device, it was difficult to read the information which needs to add an external magnetic field, may change after the information (the magnetization direction of a free layer) currently written in by this external magnetic field reads, and is written in by un-destroying.

[0007] The example of the magnetic thin film of the induction ferry mold which carried out the laminating of the soft magnetism layer (software layer) set to [induction ferry mold] Jpn.J.Appl.Phys.33(1994) L1668 from the high hard magnetism layer (hard layer) and high NiFeCo of the coercive force which consists of CoPt through the non-magnetic layer Cu is shown. In this magnetic thin film, when it is the case where the magnetization direction of a hard layer and a software layer is the same direction, and hard flow, that resistance changes.

[0008] As a magnetic-thin-film memory device using this magnetic thin film, Jpn.J.Appl.Phys.Part2 and the thing shown in 34 (1994)L415 are known. In this magnetic-thin-film memory device, since information is written in a hard layer, it can read, without destroying the information currently written in.

[0009] Here, the case where it reads with the case where information is written in this magnetic-thin-film memory device is explained from drawing 12 with reference to the mimetic diagram of the thin film cross section shown in drawing 14 R> 4.

[0010] Drawing 12 shows the case where information is written in this magnetic-thin-film memory device. As shown in this drawing, this magnetic-thin-film memory device consists of the software layer (magnetic layer) 41 and the hard layer (magnetic layer) 42 by which the laminating was carried out through the non-magnetic layer 43. Moreover, 10 is a write-in line which generates an external magnetic field, and the software layer 41 and the hard layer 42 are magnetized in the direction of the external magnetic field which generated the write-in line 10 according to the flowing current. And when it is drawing 12 (a) by which binary "0" and "1" are assigned in the two magnetization directions of the hard layer 42, Counterclockwise external magnetic field 10a occurs [consequently]. The magnetization direction of the software layer 41 41a, The magnetization direction of the hard layer 42 is set to 42a, and, in (b), clockwise external magnetic field 10b occurs, consequently 41b and the magnetization direction of the hard layer 42 are set to 42b by the magnetization direction of the software layer 41. In addition, in writing, it is necessary to add the external magnetic field of sufficient reinforcement to change the magnetization direction of not only the software layer 41 but the hard layer 42.

[0011] Drawing 13 shows the case where the information written in by external magnetic field 10a of the counterclockwise rotation shown in drawing 12 (a) is read. Usually, in this order, weak external magnetic field 10b of a clockwise rotation as indicated the information written in the magnetic-thin-film memory device to be weak (magnetic field strength from which only the magnetization direction of the software layer 41 changes) external magnetic field 10a of a counterclockwise rotation when reading, as shown in drawing 13 (a) to (b) writes in so that it may be added to a magnetic-thin-film memory device, and it passes a current on a line 10. Under the present circumstances, Current Ir is passed on the read-out line 5 linked to a magnetic-thin-film memory device.

[0012] Here, since magnetization direction 41a of the software layer 41 and magnetization direction 42a of the hard layer 42 become in the same direction when counterclockwise weak external magnetic field 10a is added, and magnetization direction 41b of the software layer 41 and magnetization direction 42a of the hard layer 42 become hard flow when clockwise weak external magnetic field 10a is added, the resistance of a magnetic-thin-film memory device changes with change of this external magnetic field from low resistance to high resistance. Therefore, the electrical potential difference V of the output side of a magnetic-thin-film memory device descends at the time of change of an external magnetic field.

[0013] Drawing 14 shows the case where the information written in by external magnetic field 10b of the clockwise rotation shown in drawing 8 (b) is read.

[0014] When weak external magnetic field 10a of a counterclockwise rotation as shown in (a) is

added here When magnetization direction 41a of the software layer 41 and weak external magnetic field 10a of a clockwise rotation as shown in (b) by magnetization direction 42b of the hard layer 42 becoming hard flow are added Since magnetization direction 41b of the software layer 41 and magnetization direction 42b of the hard layer 42 become in the same direction, the resistance of a magnetic-thin-film memory device changes with change of this external magnetic field from high resistance to low resistance. Therefore, the electrical potential difference V of the output side of a magnetic-thin-film memory device rises at the time of change of an external magnetic field.
[0015] As mentioned above, when changing the external magnetic field added more at a magnetic-thin-film memory device to change the current which flows the write-in line 10, a difference arises according to the magnetization direction of the hard layer 42 in fluctuation (a rise or descent) of the electrical potential difference V of the output side of a magnetic-thin-film memory device. Therefore, the information memorized as a magnetization direction of the hard layer 42 can be read by detecting fluctuation of this electrical potential difference V.
[0016]
[Problem(s) to be Solved by the Invention] However, in order to carry out the four or more layer laminating of the very thin magnetic layer of Thickness 10-200A, and the conductive non-magnetic layers, such as Cu, structure and a production process became complicated, and the magnetic-thin-film memory device from which giant magneto-resistance is obtained had the high manufacturing cost.
[0017] moreover, the memory device to which a memory device is arranged in the shape of a matrix, and is located in a line with length or a longitudinal direction by the usual magnetic-thin-film memory -- reading -- a line -- a serial -- connection -- now, it is. The thickness of this memory device is very as thin as hundreds A, and since that resistance is high, when magnetic-thin-film memory is constituted and a current is passed on a read-out line, the power loss by generation of heat and generation of heat becomes large. Therefore, it was difficult to make [many] an element number and to enlarge capacity of memory.
[0018] Then, it is proposed in view of this conventional actual condition, and structure consists of a simple three-tiered structure, there are few power losses at low resistance, and this invention aims at offering the magnetic-thin-film memory device in which large-capacity-izing is possible, and magnetic-thin-film memory.
[0019]
[Means for Solving the Problem] The magnetic-thin-film memory device concerning this invention has the 1st magnetic layer and the 2nd magnetic layer with an parallel easy axis by which the laminating was carried out on both sides of the insulating layer, the coercive force of this 2nd magnetic layer is larger than the coercive force of this 1st magnetic layer, and it is characterized by there being a part from which the tunnel effect is acquired between this 1st magnetic layer and this 2nd magnetic layer.
[0020] Moreover, the magnetic-thin-film memory device concerning this invention is characterized by using diamond-like carbon as an ingredient of the insulating layer inserted into the 1st magnetic layer of the above, and the 2nd magnetic layer.
[0021] Moreover, the magnetic-thin-film memory device concerning this invention is characterized by using poly paraxylene as an ingredient of the insulating layer inserted into the 1st magnetic layer of the above, and the 2nd magnetic layer.
[0022] Moreover, the magnetic-thin-film memory device concerning this invention is characterized by using the oxide which contains aluminum as an ingredient of the insulating layer inserted into the 1st magnetic layer of the above, and the 2nd magnetic layer.
[0023] Moreover, it is characterized by the magnetic-thin-film memory concerning this invention having two write-in lines by which said magnetic-thin-film component compared with the storage element part in which the magnetic-thin-film memory device of one of the above was arranged in the shape of a matrix in length or a longitudinal direction was connected to the serial and which read and were formed in the direction perpendicular to a direction parallel to a line and this read-out line through the insulating material.
[0024]
[Function] According to the magnetic-thin-film memory device concerning this invention, big

magnetic-reluctance rate of change (MR rate of change) can be obtained by the simple three-tiered structure.
[0025] Moreover, since the current which flows an insulating layer according to the tunnel effect flows in the direction perpendicular to the stratification plane of an insulating layer, it can make small resistance of a magnetic-thin-film memory device.
[0026] Moreover, when the oxide which uses diamond RAIKUKA-Bonn, the poly PARAKI silylene, or aluminum as a principal component is used as an ingredient of an insulating layer, the tunnel junction from which the tunnel effect is acquired can be formed easily.
[0027] Moreover, according to the magnetic-thin-film memory using the magnetic-thin-film memory device concerning this invention, since it is a three-tiered structure with a simple memory device, magnetic-thin-film memory can be manufactured by the simple production process.
[0028] Moreover, according to the magnetic-thin-film memory using the magnetic-thin-film memory device concerning this invention, resistance of a component is small, and in the condition of not impressing a field, since a component will be in a low resistance condition, while large capacity-ization of memory is attained, the magnetic-thin-film memory of a low power can be offered.
[0029]
[Example]
The magnetic-thin-film memory device concerning [configuration of magnetic-thin-film memory device concerning this invention] this invention has the three-tiered structure which carried out the tunnel junction of the 1st magnetic layer and the 2nd magnetic layer through the insulating layer, and uses the magnetic tunneling effectiveness of appearing between the 1st magnetic layer of the above, and the 2nd magnetic layer. Even if it separates a metal and a semi-conductor by the thin insulating layer and generally makes the potential barrier, conduction electron passes an insulating layer to some extent according to the tunnel effect. Moreover, since it depends for the electronic state of a ferromagnetic metal on spin, depending on whenever [angular relation / of the magnetization direction of these magnetic layers] for the tunnel effect which shows up between the 1st magnetic layer of the above and the 2nd magnetic layer is known (J. Magn.Magn.Mater.98(1991) L7-L9). And the magneto-resistive effect in such a part by which the tunnel junction was carried out is called magnetic tunneling effectiveness.
[0030] Moreover, the easy axis of the 1st magnetic layer and the 2nd magnetic layer contributed to the above-mentioned magnetic tunneling effectiveness is parallel, and the coercive force of the 2nd magnetic layer is larger than the coercive force of the 1st magnetic layer. Therefore, only the 1st magnetic layer can change the magnetization direction of the both sides of the 1st magnetic layer and the 2nd magnetic layer by adjusting the reinforcement of the external magnetic field added to the 1st magnetic layer and the 2nd magnetic layer.
[0031] And electric resistance becomes low according to the above-mentioned magnetic tunneling effectiveness at the time of the same direction, and the magnetization direction of the 1st magnetic layer and the 2nd magnetic layer becomes high at the time of hard flow (180-degree hard flow). therefore, the case (for example, when the magnetization direction is changed rightward from the left) where the magnetization direction of only the 1st magnetic layer is changed in fixed sequence by the external magnetic field -- the magnetization direction of the 2nd magnetic layer -- responding -- electric resistance -- the high resistance from low resistance -- or it changes from high resistance to low resistance.
[0032] Here, since the magnetization direction needs to change by the weakest possible external magnetic field, the smaller one of coercive force is good and the 1st magnetic layer is below 10 [Oe] more preferably below 50 [Oe]. It is because the current which generates a strong external magnetic field is needed when changing the magnetization direction, so it may malfunction by generation of heat and a noise increasing when magnetic-thin-film memory is constituted when it is larger than 50 [Oe] to have made the range of coercive force below into 50 [Oe] here. In addition, although the magnitude of the coercive force of a magnetic layer can be set as predetermined magnitude by adjusting a presentation, thickness, and membrane formation conditions, as for thickness, it is desirable that it is 5-100nm. It is because the film becomes island-like, so electric resistance becomes high and is not desirable if thinner than 5nm. Moreover, Fe, NiFe, NiFeCo, etc. can be used as an ingredient of the 1st magnetic layer.

[0033] On the other hand, it is necessary to make coercive force of the 2nd magnetic layer larger than the coercive force of the 1st magnetic layer, and it is more than 100 [Oe] more preferably more than 50 [Oe]. It is because the magnetization direction may be disturbed under the effect of an external turbulence field etc. and memory may be destroyed, if it is smaller than 50 [Oe] to have carried out the range of coercive force to more than 50 [Oe] here. In addition, by adjusting a presentation, thickness, and membrane formation conditions, the magnitude of the coercive force of the 2nd magnetic layer can also be set as predetermined magnitude, and it is [as well as the 1st magnetic layer] desirable about thickness that it is 5-100nm. Moreover, Co, CoFe, CoPt, MnSb, etc. can be used as an ingredient of the 2nd magnetic layer.
[0034] The difference of the coercive force of the 1st magnetic layer of the above and the 2nd magnetic layer is required for more than 20 [Oe], and is more than 100 [Oe] more preferably more than 50 [Oe]. It is because the permission fluctuation range of the current for generating the permission fluctuation range of the external magnetic field added in order to change only the magnetization direction of the 1st magnetic layer, i.e., this external magnetic field, when reading information will become small if having carried out the difference of coercive force to more than 20 [Oe] here has the difference of coercive force smaller than 20 [Oe].
[0035] Moreover, in order to acquire the above-mentioned magnetic tunneling effectiveness, it is necessary to make thin to homogeneity thickness of the insulating layer inserted into the 1st magnetic layer of the above, and the 2nd magnetic layer, and the range of it is 1-10nm more preferably 1-20nm. It is because the tunneling effectiveness will not happen if thicker [if it is thinner than 1nm to have set the range of the thickness of an insulating layer to 1-20nm here, a pinhole will increase and the uniform potential barrier will not be formed, but] than 20nm. Therefore, although the oxide which uses diamond RAIKUKA-Bonn (henceforth DLC), the poly PARAKI silylene, and aluminum as a principal component is mentioned as an ingredient with which the ingredient with little generating of a pinhole etc. was needed and with which film thickness was also suitable for this as an ingredient of an insulating layer, it is desirable to use DLC or the poly PARAKI silylene.
[0036] The case where information is written in the magnetic-thin-film memory device concerning [principle of operation of magnetic-thin-film memory device concerning this invention] this invention, and the case where it reads from a magnetic-thin-film memory device are explained from drawing 1 with reference to the mimetic diagram of the thin film cross section shown in drawing 3 .
[0037] Drawing 1 shows the case where information is written in this magnetic-thin-film memory device. As shown in this drawing, this magnetic-thin-film memory device consists of the 1st magnetic layer 1 and the 2nd magnetic layer 2 by which the laminating was carried out through the insulating layer 3. Moreover, 10 is a write-in line which generates an external magnetic field, and the 1st magnetic layer 1 and the 2nd magnetic layer 2 are magnetized in the direction of the external magnetic field which generated the write-in line 10 according to the flowing current. And binary "0" and "1" are assigned in the magnetization direction of the 2nd magnetic layer 2.
[0038] In the case of drawing 1 (a), by counterclockwise external magnetic field 10a occurring according to the current which flows the write-in line 10 consequently, 1a and the magnetization direction of the 2nd magnetic layer 2 are set to 2a, and, as for the magnetization direction of the 1st magnetic layer 1, in (b), clockwise external magnetic field 10b generates them, consequently, in 1b and the magnetization direction of the 2nd magnetic layer 2, the magnetization direction of the 1st magnetic layer 1 becomes 2b. In addition, in writing, it is necessary to add the external magnetic field of sufficient reinforcement to change the magnetization direction of not only the 1st magnetic layer 1 but the 2nd magnetic layer 2.
[0039] Drawing 2 shows the case where the information written in by external magnetic field 10a of the counterclockwise rotation shown in drawing 1 (a) is read. Usually, in this order, weak external magnetic field 10b of a clockwise rotation as indicated the information written in the magnetic-thin-film memory device to be weak (magnetic field strength from which only the magnetization direction of the 1st magnetic layer 1 changes) external magnetic field 10a of a counterclockwise rotation when reading, as shown in drawing 2 (a) to (b) writes in so that it may be added to a magnetic-thin-film memory device, and it passes a current on a line 10. Under the present circumstances, Current Ir is passed on the read-out line 5 linked to a magnetic-thin-film memory device.

[0040] When counterclockwise weak external magnetic field 10a is added, here When magnetization direction 1a of the 1st magnetic layer 1 and magnetization direction 2a of the 2nd magnetic layer 2 become in the same direction and add clockwise weak external magnetic field 10a Since magnetization direction 1b of the 1st magnetic layer 1 and magnetization direction 2a of the 2nd magnetic layer 2 become hard flow, the resistance of a magnetic-thin-film memory device changes with change of this external magnetic field from low resistance to high resistance. Therefore, when it is made to change at the time of change of an external magnetic field, i.e., the current which flows the write-in line 10, the electrical potential difference V of the output side of a magnetic-thin-film memory device descends.
[0041] Drawing 3 shows the case where the information written in by external magnetic field 10b of the clockwise rotation shown in drawing 1 (b) is read.
[0042] When counterclockwise weak external magnetic field 10a is added, here When magnetization direction 2b of the 2nd magnetic layer 2 becomes magnetization direction 1a of the 1st magnetic layer 1 to hard flow and clockwise weak external magnetic field 10a is added Since magnetization direction 1b of the 1st magnetic layer 1 and magnetization direction 2b of the 2nd magnetic layer 2 become in the same direction, the resistance of a magnetic-thin-film memory device changes with change of this external magnetic field from high resistance to low resistance. Therefore, the electrical potential difference V of the output side of a magnetic-thin-film memory device rises at the time of change of an external magnetic field.
[0043] As mentioned above, when changing the external magnetic field added more at a magnetic-thin-film memory device to change the current which flows the write-in line 10, a difference arises according to the magnetization direction of the 2nd magnetic layer 2 in fluctuation of the electrical potential difference V of the output side of a magnetic-thin-film memory device.
[0044] In addition, when an external magnetic field is removed and the magnetization direction of the 1st magnetic layer differs from the magnetization direction of the 2nd magnetic layer, the magnetization direction of the 1st magnetic layer returns in the same direction as the magnetization direction of the 2nd magnetic layer with larger coercive force than the 1st magnetic layer. Therefore, since all the components that are not adding the external magnetic field become low resistance when a magnetic-thin-film memory device is arranged in the shape of a matrix and magnetic-thin-film memory is constituted, power loss by generation of heat and generation of heat can be made small.
[0045] Drawing 4 (a) shows fluctuation of the electrical potential difference V of the output side of the magnetic-thin-film memory device when passing the playback pulse current (b) and (c) indicated the current (henceforth playback pulse current) which changes from + side which flows a write-in line to - side to be to (a), when reading information. Here, as shown in (a) of this drawing, when the current which flows a write-in line changes from + side to - side, the external magnetic field added to a magnetic-thin-film memory device changes. that is, the time of the field of drawing 2 and the counterclockwise rotation shown in 3 occurring at the time of + side, and being - side -- drawing 2 R> -- the field of the counterclockwise rotation shown in 2 and 3 occurs. And at the time of this change, according to the magnetization direction of the 2nd magnetic layer, the electrical potential difference V of the output side of a magnetic-thin-film memory device rises, as shown at (b), or as shown in (c), it descends. Therefore, when reading information, the magnetization direction of the 2nd magnetic layer can be judged by detecting the voltage variation produced on the read-out line which connects with a sink at a write-in line, and connects playback pulse current with the output side of a magnetic-thin-film memory device then.
[0046] Moreover, when reading information, even if it passes only the current by the side of + as shown in drawing 4 (d), the magnetization direction of the 2nd magnetic layer can be judged. In this case, when reading information, only the field (drawing 2 , field of the counterclockwise rotation shown in 3) by the current by the side of + is impressed to a magnetic-thin-film memory device. And when this current is passed, according to the magnetization direction of the 2nd magnetic layer, the electrical potential difference V of the output side of a magnetic-thin-film memory device is not changed, as shown in (e), or as shown in (c), it is changed (it falls). Therefore, when a current is passed, the magnetization direction of the 2nd magnetic layer can be judged by detecting whether voltage variation arises.
[0047] In addition, since the two magnetization directions of the 2nd magnetic layer are assigned to

binary "0" and "1", a setup of the magnetization direction of the 2nd magnetic layer corresponds to the writing of the information on a magnetic-thin-film memory device, and detection of the magnetization direction of the 2nd magnetic layer corresponds to read-out of the information from a magnetic-thin-film memory device.
[0048] The magnetic-thin-film memory concerning [magnetic-thin-film memory concerning this invention] this invention is explained with reference to drawing 8 from drawing 5 .
[0049] Drawing 5 shows the top view (a) and its AA' sectional view (b) of the one-element part in magnetic-thin-film memory, and the laminating of the 1st magnetic layer 1 and the 2nd magnetic layer 2 linked to the read-out line 5 is carried out through the insulating layer 3. Here, the tunnel junction of the 1st magnetic layer 1 and the 2nd magnetic layer 2 is carried out, and the part which the 1st magnetic layer 1 and the 2nd magnetic layer 2 overlapped becomes the tunnel junction section. Moreover, coercive force of the 2nd magnetic layer 2 is made larger than the coercive force of the 1st magnetic layer 1.
[0050] In addition, in the magnetic-thin-film memory device of this invention, since a current flows in the direction perpendicular to the film surface of an insulating layer 3 as shown in the arrow head 8, resistance of a component becomes small, and generation of heat of a component can lessen the read-out current which flows the tunnel junction section. Moreover, formation of the component of subMIKURONO-DA - is attained, and it can large-capacity-ize memory.
[0051] Moreover, the write-in line 10 is formed in the direction perpendicular to the easy axis 4 of the above-mentioned magnetic-thin-film memory device, and the write-in auxiliary line 20 is formed in the parallel direction. And the above-mentioned magnetic-thin-film memory device, the write-in line 10, and the write-in auxiliary line 20 are insulated by the insulator layer 7 and the insulator layer 6.
[0052] The magnetic-thin-film memory device is arranged in the shape of a matrix by the part with which drawing 6 indicates the top view (a) and its BB' sectional view (b) of magnetic-thin-film memory to be, and writes in with the write-in lines 11, 12, and 13, and the part and auxiliary lines 21, 22, and 23 cross at right angles. Here, it connects with a serial in the direction of a read-out auxiliary line, and the magnetic-thin-film memory device forms the read-out line. For example, in the part shown in BB' cross section, the part by which the magnetic-thin-film memory devices 31, 32, and 33 were connected to the serial becomes the read-out line 5.
[0053] Thus, when write-in current sufficient when the magnetic-thin-film memory device is arranged in the shape of a matrix to change the magnetization direction of the 2nd magnetic layer of a magnetic-thin-film memory device to a write-in line is passed, all of the 1st magnetic layer and the 2nd magnetic layer of the magnetic-thin-film memory which passed the write-in current and which wrote in and was arranged along with the line will be magnetized in the direction of the field generated according to the write-in current. That is, writing is altogether performed in the magnetic-thin-film memory which passed the write-in current and which wrote in and was arranged along with the line. Therefore, when a magnetic-thin-film memory device is arranged in the shape of a matrix, information cannot be written only with the current which flows one write-in line in making only the magnetization direction of some components of a magnetic-thin-film memory device turn to in the desired magnetization direction, i.e., some components.
[0054] Here, when making only the magnetization direction of some components of the magnetic-thin-film memory device arranged in the shape of a matrix by writing in with a write-in line and passing a current to the both sides of an auxiliary line turn to in the desired magnetization direction that is, the case where information is written only in some components is explained with reference to drawing 7 and drawing 8 .
[0055] In drawing 7 (a), Iw1 shows the write-in current which flows the write-in line 10, and Iw shows the write-in auxiliary current which flows the write-in auxiliary line 20. And Hw1 shows the write-in auxiliary [which wrote in, showed the field and generated Hw according to the write-in auxiliary current Iw] field when it generated according to the write-in current Iw1. Here, both, since it is smaller than the coercive force of the 2nd magnetic layer of a magnetic-thin-film memory device, the write-in field Hw1 and the write-in auxiliary field Hw cannot change the magnetization direction of the 2nd magnetic layer only by one field. However, it writes in with the write-in field Hw1, and since the synthetic field H1 of the auxiliary field Hw is larger than the coercive force of

the 2nd magnetic layer, when it writes in with the write-in current Iw1 and the both sides of the auxiliary current Iw are poured, the magnetization direction of the 2nd magnetic layer can be changed.
[0056] Drawing 7 (b) shows the easy axis 4 of the write-in field Hw1, the write-in auxiliary field Hw, the synthetic field H1, and the 2nd magnetic layer 2. Here, since the synthetic field H1 is larger than the coercive force of the 2nd magnetic layer 2, the 2nd magnetic layer 2 is magnetized by the synthetic field H1, and the magnetization direction B1 becomes in the direction of a component parallel to the easy axis 4 of the synthetic field H1. In addition, the write-in field Hw1 generated according to the write-in current Iw1 is almost parallel to the easy axis 4 of the 2nd magnetic layer 2, and since the write-in auxiliary field Hw generated according to the write-in auxiliary current Iw is almost perpendicular to the easy axis 4 of the 2nd magnetic layer 2, the magnetization direction B1 is decided by the write-in field Hw1 Iw1, i.e., a write-in current.
[0057] Drawing 8 (a) is written in in the direction contrary to the write-in current Iw1 of drawing 7 , and is passing the current Iw2. Therefore, the direction of the write-in field Hw2 to generate also becomes in the direction contrary to the write-in field Hw1 of drawing 7 . Therefore, as shown in (b), magnetization direction B-2 of the 2nd magnetic layer also becomes in the direction contrary to the magnetization direction B1 of drawing 7 .
[0058] As mentioned above, in the shape of a matrix, when a magnetic-thin-film memory device is arranged, only the magnetization direction of the magnetic-thin-film memory device of the part can be changed by passing a current only to the write-in line and the write-in auxiliary line which pass along the part of the magnetic-thin-film memory device to which the magnetization direction wants to change. Moreover, the magnetization direction of a magnetic-thin-film memory device can turn a write-in line towards desired according to the direction of the flowing current.
[0059] In reading the information written in the magnetic-thin-film memory device arranged in the shape of a matrix on the other hand While reading to the read-out line to which the magnetic-thin-film memory device to read was connected and passing a current The magnetization direction of the 2nd magnetic layer which is the written-in information can be distinguished by detecting the voltage variation of a read-out line when passing a sink and playback pulse current for playback pulse current on the write-in line which passes along the part of the magnetic-thin-film memory device.
[0060] (Example 1) Co was used as the 2nd large magnetic layer 2 of Fe and coercive force as the 1st small magnetic layer 1 of coercive force, DLC was used as an insulating layer 3, and the ferromagnetic tunnel junction and magnetic-thin-film memory device of Fe(50nm)/DLC(2nm)/Co (50nm) were produced. Drawing 9 shows the perspective view (a) and mimetic diagram (b) of a sample which were produced in order to investigate the magnetic-reluctance curve of the ferromagnetic tunnel junction 9. In addition, the magnetic-reluctance curve was measured under the impression magnetic field 500 [Oe] by the direct-current 4 terminal method. Moreover, Fe/DLC/Co3 layer membrane of the magnitude of 10mm angle was also produced, and the magnetization curve was investigated by VSM.
[0061] The process which forms a ferromagnetic tunnel junction in below is explained.
[0062] First, Fe layer was formed by 50nm of thickness on the glass substrate on the membrane formation conditions shown below by DC spatter.
[0063]
ultimate-pressure force 5x10-5 PaAr gas 10 SCCM membrane formation pressure 0.5 Pa injection power 100 W membrane formation rate 0.5 nm/sec -- patterning of the Fe layer obtained in this way was carried out to the 1mmx10mm rectangle using ultra-fine processing technology, and it was used as the 1st magnetic layer 1.
[0064] Next, the DLC film was formed by 2nm of thickness on the 1st magnetic layer 1 on the membrane formation conditions shown below by the plasma-CVD method.
[0065]
Ultimate-pressure force 3x10-3 Pa ethylene gas 10 SCCM membrane formation pressure 3 Pa injection power 100 W membrane formation rate Micro processing of the DLC film obtained by carrying out 10 nm/min **** was carried out to phi3mm, and it was made into the insulating layer 3.

[0066] Then, this was again moved to DC sputtering system, and Co layer was formed by 50nm of

thickness on the following membrane formation conditions.

[0067]

ultimate-pressure force 5x10-5 PaAr gas 10 SCCM membrane formation pressure 0.5 Pa injection power 100 W membrane formation rate 0.5 nm/sec -- patterning of the Co layer obtained in this way was carried out to the shape of a 1mmx10mm stripe with ultra-fine processing technology like the 1st magnetic layer, the ferromagnetic tunnel junction 9 of Fe/DLC/Co whose plane-of-composition product is 1mmx1mm was formed, and the magnetic-reluctance curve was investigated.

[0068] Moreover, the 10mmx10mm tunnel junction was formed by the same approach, and the magnetization curve was also investigated. Consequently, the magnetic-reluctance curve shown in drawing 10 and the magnetization curve by VSM shown in drawing 11 were obtained. Here, MR rate of change shown in drawing 10 was given by x(deltaR/R) 100 (R: resistance, the amount of deltaR:resistance value changes), and 12% of MR rate of change was obtained below by the impression magnetic field 100 [Oe] by the sample of this example.

[0069] The magnetic-thin-film memory device as shown in drawing 5 using this Fe/DLC/Co ferromagnetism tunnel junction was produced at the process as follows.

[0070] First, after forming Fe layer by 50nm of thickness, impressing the magnetic field of 500 [Oe] in the direction which forms the read-out line on a glass substrate, patterning was carried out to the 2micrometerx10micrometer rectangle using ultra-fine processing technology, and it considered as the 1st magnetic layer 1. Thus, the easy axis of the formed magnetic layer becomes parallel to the direction of the impressed magnetic field by forming membranes, impressing a magnetic field.

[0071] Next, on the 1st magnetic layer 1, the diamond RAIKUKA-Bonn (DLC) film was formed 2nm of thickness, and carried out micro processing, and it considered as the insulating layer 3.

[0072] Then, after forming Co layer by 50nm of thickness, having moved this to DC sputtering system again, and impressing the same magnetic field as the case of Fe layer, patterning was carried out to the shape of a 1micrometerx10micrometer stripe with ultra-fine processing technology, and it considered as the 2nd magnetic layer 2. The plane-of-composition product formed the tunnel junction of Fe/DLC/Co which is 1micrometerx3micrometer according to the above process.

[0073] Next, the Cr(5nm)/Au(200nm)/Cr (5nm) film was read, and it formed as a line 5 so that it might connect with the 1st magnetic layer 1 and the 2nd magnetic layer 2.

[0074] Then, after forming the insulator layer 7 which consists of an alumina 200nm of thickness by RF spatter, the Cr(5nm)/Au(200nm)/Cr (5nm) film was formed again, and it read to the upper part of the tunnel junction section, and patterning was carried out to band-like, it wrote in in the direction parallel to a line 5, and the auxiliary line 20 was formed. Furthermore, the write-in line 10 by which patterning was carried out to band-like was formed in the direction which writes in with the insulator layer 6 which consists of an alumina of 200nm of thickness, and carries out a right angle to an auxiliary line 20 by the same approach, and it considered as the magnetic-thin-film memory device.

[0075] In this way, when the check of the obtained magnetic-thin-film memory of operation was performed, writing and read-out were able to be performed normally. That is, at the time of writing, desired voltage variation was able to be obtained from the read-out line by passing playback pulse current at the time of read-out by magnetizing the 1st magnetic layer 1 and the 2nd magnetic layer 2 of a magnetic-thin-film memory device in the direction of the field generated according to the write-in current.

[0076] (Example 2) By the same approach as an example 1, the ferromagnetic tunnel junction of the film configuration of a publication was produced to Table 1, the magnetic-reluctance curve was investigated, and the obtained magnetic-reluctance rate of change was shown in Table 1. As shown in this table, it has checked that 5 - 25% of MR rate of change was obtained also about which sample.

[0077] Next, when the magnetic-thin-film memory device using these ferromagnetic tunnel junctions was produced and the check of operation was performed like the example 1, writing and read-out were able to be performed normally.

[0078] The ferromagnetic tunnel junction which made the diamond RAIKUKA-Bonn film the insulating layer with the film configuration given in Table 1 by the approach with the same said of a comparison sample was produced, the magnetic-reluctance curve was investigated, and the obtained magnetic-reluctance rate of change was shown in Table 1. As shown in this table, neither of the

comparison samples was obtained only for 0.1 - 0.2% of MR rate of change. Since a uniform insulating layer is not formed as this reason when insulating thickness is as thin as 1nm, a pinhole increases, and it thinks because an electric bridge will be formed between two magnetic layers. Moreover, when insulating thickness is as thick as 30nm, it thinks because tunnel current will be scattered about.

[0079] Next, when the magnetic-thin-film memory device using the ferromagnetic tunnel junction of a comparison sample was produced and the check of operation was performed like the above-mentioned sample, it did not operate normally.

[0080]

[Table 1]

サンプル	第1磁性層	第1磁性層厚 (nm)	第2磁性層	第2磁性層厚 (nm)	絶縁層	絶縁層厚 (nm)	MR変化率 (%)
試料1	Fe	50	Co	50	DLC	2	12
試料2	$Ni_{80}Fe_{20}$	10	Co	20	DLC	5	5
試料3	$Fe_{50}Co_{50}$	80	Co	5	DLC	3	15
試料4	$Ni_{80}Fe_{20}$	5	$Fe_{50}Co_{50}$	10	DLC	10	7
試料5	Fe	50	$Fe_{50}Co_{50}$	50	DLC	6	28
比較試料1	Fe	5	Co	5	DLC	1	0.2
比較試料2	$Ni_{80}Fe_{20}$	10	Co	20	DLC	30	0.1

[0081] (Example 3) By the same approach as an example 1, the ferromagnetic tunnel junction which made the poly PARAKI silylene the insulating layer was produced with the film configuration given in Table 2, the magnetic-reluctance curve was investigated, and the obtained magnetic-reluctance rate of change was shown in Table 2. As shown in this table, it has checked that 6 - 13% of MR rate of change was obtained also about which sample.

[0082] In addition, the poly PARAKI silylene film was produced by the following approaches here. First, after evaporating the JIPARA xylylene of a raw material at about 150 degrees C under a vacuum, it pyrolyzed at 600 degrees C in the furnace, and the poly PARAKI silylene film was produced by reaction pressure 20mTorr at the membrane formation room. The membrane formation rate formed Parylene N and Parylene C of Union Carbide by 10 nm/min as poly PARAKI silylene.

[0083] Next, when the magnetic-thin-film memory device using these ferromagnetic tunnel junctions was produced and the check of operation was performed like the example 1, writing and read-out were able to be performed normally.

[0084] The ferromagnetic tunnel junction which made the insulating layer the poly PARAKI silylene or polo monochrome PARAKI silylene with the film configuration given in Table 2 by the approach with the same said of a comparison sample was produced, the magnetic-reluctance curve was investigated, and the obtained magnetic-reluctance rate of change was shown in Table 2. As shown in this table, neither of the comparison samples was obtained only for 0.1 - 0.3% of MR rate of change. Since a uniform insulating layer is not formed as this reason when insulating thickness is as thin as 1nm, a pinhole increases, and it thinks because an electric bridge will be formed between two magnetic layers. Moreover, when insulating thickness is as thick as 25nm, it thinks because tunnel current will be scattered about.

[0085] Next, when the magnetic-thin-film memory device using the ferromagnetic tunnel junction of a comparison sample was produced and the check of operation was performed like the above-mentioned sample, it did not operate normally.

[0086]

[Table 2]

サンプル	第1磁性層	第1磁性層厚 (nm)	第2磁性層	第2磁性層厚 (nm)	絶縁層	絶縁層厚 (nm)	MR変化率 (%)
試料6	$Fe_{50}Co_{50}$	20	Co	30	ﾊﾟﾘﾚﾝN	15	13
試料7	$Ni_{66}Fe_{16}Co_{18}$	10	$Fe_{50}Co_{50}$	10	ﾊﾟﾘﾚﾝN	7	9
試料8	$Ni_{80}Fe_{20}$	20	$Fe_{50}Co_{50}$	20	ﾊﾟﾘﾚﾝC	10	6
試料9	$Ni_{66}Fe_{16}Co_{18}$	10	Co	30	ﾊﾟﾘﾚﾝC	7	7
比較試料3	$Fe_{50}Co_{50}$	20	Co	30	ﾊﾟﾘﾚﾝN	25	0.3
比較試料4	$Ni_{66}Fe_{16}Co_{18}$	10	Co	30	ﾊﾟﾘﾚﾝC	1	0.1

[0087] (Example 4) By the same approach as an example 1, the ferromagnetic tunnel junction which made aluminum 2O3 the insulating layer was produced with the film configuration given in Table 3, the magnetic-reluctance curve was investigated, and the obtained magnetic-reluctance rate of change was shown in Table 3. As shown in this table, it has checked that 13 - 20% of MR rate of change was obtained also about which sample.
[0088] In addition, after 2Oaluminum3 insulating layer produced aluminum metal membrane by the spatter, in atmospheric air, natural oxidation of it was carried out for 24 hours, and it was formed here.
[0089] Next, when the magnetic-thin-film memory device using these ferromagnetic tunnel junctions was produced and the check of operation was performed like the example 1, writing and read-out were able to be performed normally.
[0090] The ferromagnetic tunnel junction which made aluminum 2O3 the insulating layer with the film configuration given in Table 3 by the approach with the same said of a comparison sample was produced, the magnetic-reluctance curve was investigated, and the obtained magnetic-reluctance rate of change was shown in Table 3. As shown in this table, by the comparison sample, only 0.2% of MR rate of change was obtained. As this reason, since the insulating layer is as thin as 1nm, a pinhole increases, and it thinks because a bridge is electrically made between up-and-down magnetic layers.
[0091] Next, when the magnetic-thin-film memory device using the ferromagnetic tunnel junction of a comparison sample was produced and the check of operation was performed like the above-mentioned sample, it did not operate normally.
[0092]
[Table 3]

サンプル	第1磁性層	第1磁性層厚 (nm)	第2磁性層	第2磁性層厚 (nm)	絶縁層	絶縁層厚 (nm)	MR変化率 (%)
試料10	$Fe_{50}Co_{50}$	20	Co	40	Al_2O_3	3	13
試料11	$Fe_{50}Co_{50}$	50	Fe	40	Al_2O_3	3	20
比較試料5	$Fe_{50}Co_{50}$	20	Co	40	Al_2O_3	1	0.2

[0093] Moreover, as a result of investigating resistance of the magnetic-thin-film memory device produced in the examples 1-3, it was very as low as 1-5ohm. This value is as low as 1/10 or less [of resistance of the spin bulb structure GMR memory device of the same magnitude].
[0094] as mentioned above -- according to [so that clearly] this invention -- the very simple three-tiered structure of a magnetic layer / insulating layer / magnetic layer -- having -- and -- low -- a magnetic-thin-film memory device [****] can be offered.
[0095]
[Effect of the Invention] Since the magnetic-thin-film memory device concerning this invention can obtain big MR rate of change by the simple three-tiered structure as explained above, it can form a magnetic-thin-film memory device by low cost.
[0096] Moreover, resistance of a magnetic-thin-film memory device can be made small, and generation of heat in a component can be lessened.
[0097] Moreover, when the oxide which uses diamond RAIKUKA-Bonn, the poly PARAKI silylene, or aluminum as a principal component is used as an ingredient of an insulating layer, the tunnel junction from which the tunnel effect is acquired can be formed easily.
[0098] Moreover, without forming a very thin magnetic layer, an electric conduction non-magnetic

layer, etc., only by the simple production process, since magnetic-thin-film memory can be manufactured, a manufacture yield can be raised.

[0099] Moreover, the magnetic-thin-film memory device concerning this invention has small resistance, and it can offer the magnetic-thin-film memory of a low power while large capacity-ization of memory is attained, since it will be in a low resistance condition in the condition of not impressing a field.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is a sectional view for explaining the write-in actuation to the magnetic-thin-film memory device concerning this invention.
[Drawing 2] It is a sectional view for explaining the read-out actuation to the magnetic-thin-film memory device concerning this invention.
[Drawing 3] It is a sectional view for explaining the read-out actuation to the magnetic-thin-film memory device concerning this invention.
[Drawing 4] It is the wave form chart having shown the voltage variation which reads according to the current wave form of playback pulse current, and playback pulse current, and is produced on a line.
[Drawing 5] It is the top view and sectional view having shown the structure of the magnetic-thin-film memory device concerning this invention.
[Drawing 6] It is the top view and sectional view having shown the configuration of the magnetic-thin-film memory concerning this invention.
[Drawing 7] It is an explanatory view for explaining the write-in actuation to the component which constitutes the magnetic-thin-film memory concerning this invention.
[Drawing 8] It is an explanatory view for explaining the write-in actuation to the component which constitutes the magnetic-thin-film memory concerning this invention.
[Drawing 9] It is the perspective view and top view having shown the sample of a tunnel junction.
[Drawing 10] It is the graph which showed the magnetic-reluctance curve in the tunnel junction of an example 1.
[Drawing 11] It is the graph which showed the magnetization curve in the tunnel junction of an example 1.
[Drawing 12] It is a sectional view for explaining the write-in actuation to the conventional magnetic-thin-film memory device.
[Drawing 13] It is a sectional view for explaining the read-out actuation to the conventional magnetic-thin-film memory device.
[Drawing 14] It is a sectional view for explaining the read-out actuation to the conventional magnetic-thin-film memory device.
[Description of Notations]
1 1st Magnetic Layer
2 2nd Magnetic Layer
3 Insulating Layer
4 Easy Axis
5 Read-out Line
6 Seven Insulator layer
10, 11, 12, 13 Write-in line
20, 21, 22, 23 Write-in auxiliary line

[Translation done.]

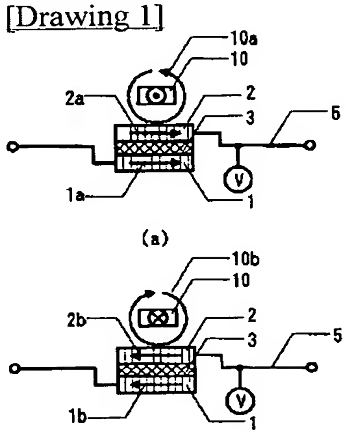
* NOTICES *

JPO and NCIPI are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

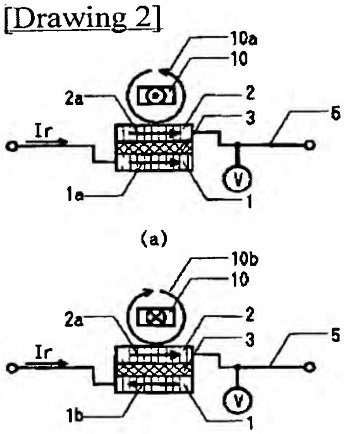
DRAWINGS

[Drawing 1]



(b)

[Drawing 2]



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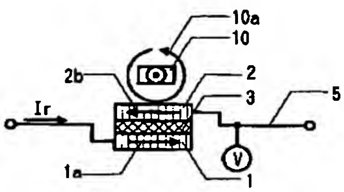
[Drawing 3]



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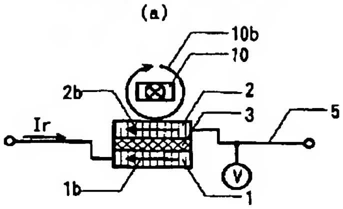

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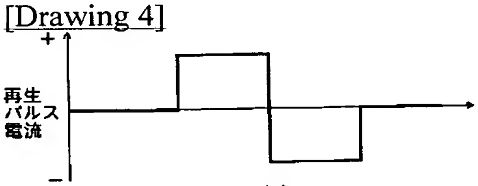
[Drawing 4]



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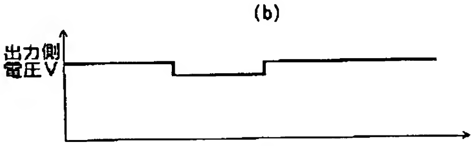

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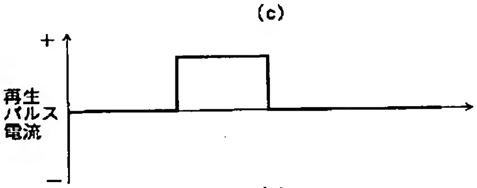

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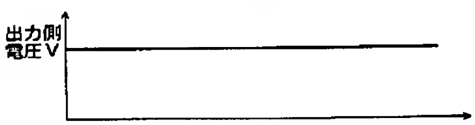

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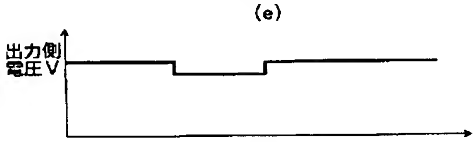

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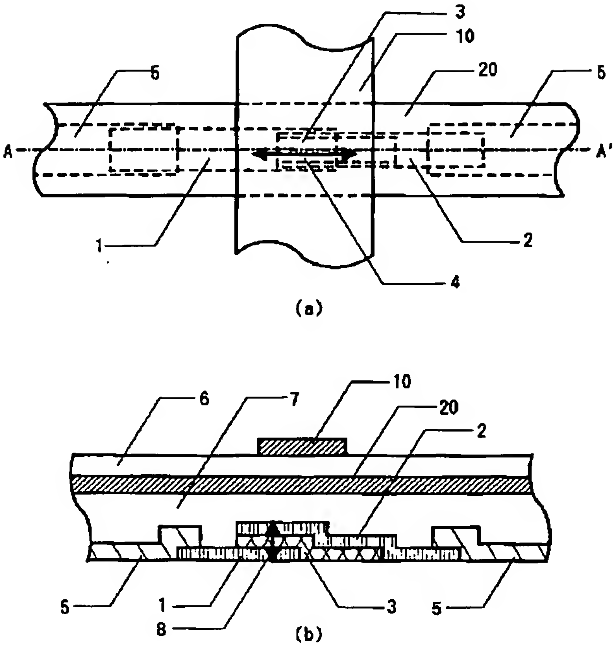
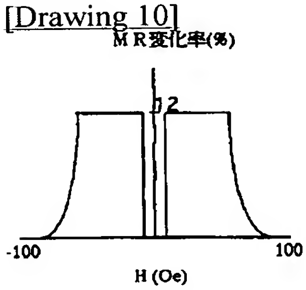
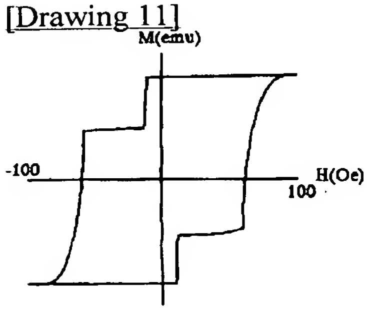
[Drawing 5]



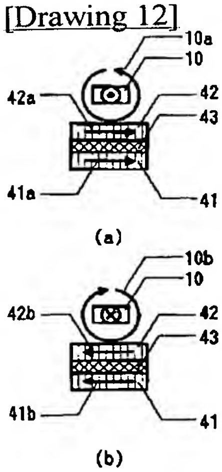
[Drawing 10]



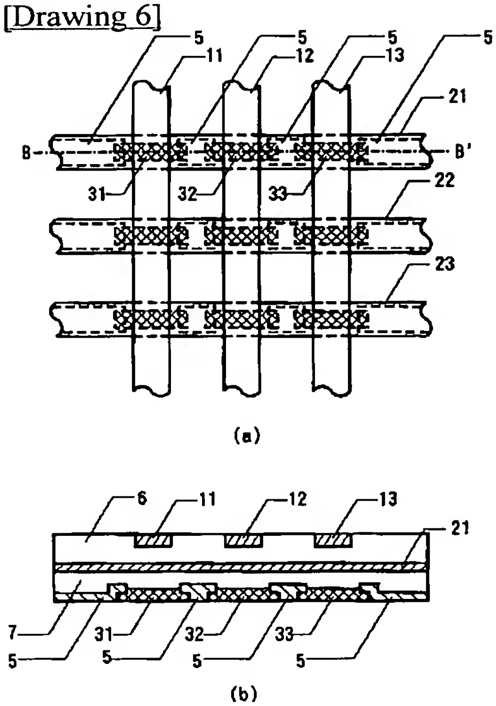
[Drawing 11]



[Drawing 12]



[Drawing 6]



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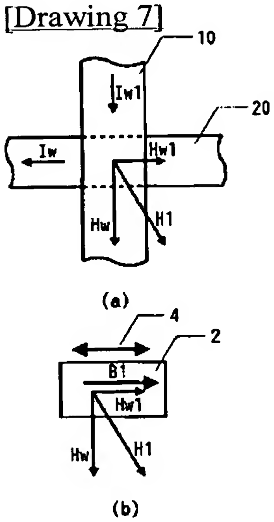
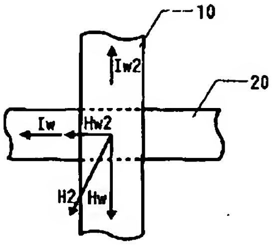


[Drawing 8]



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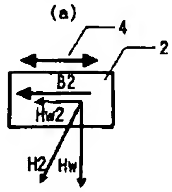
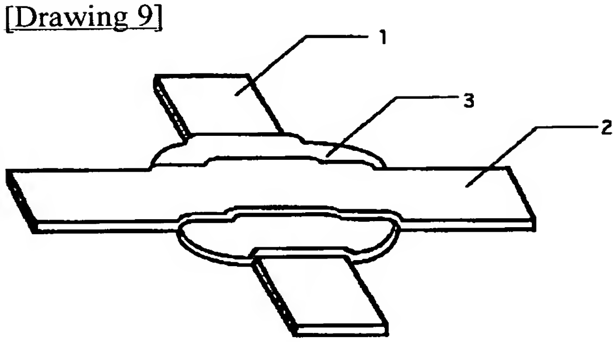
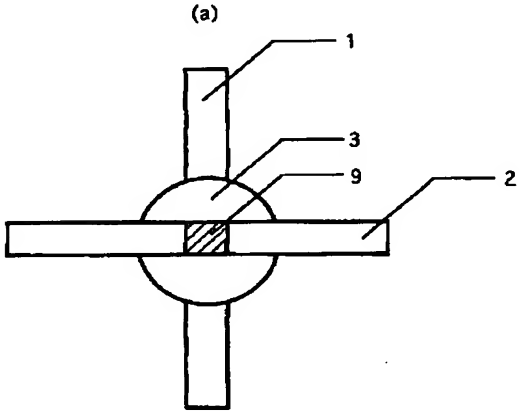


(b)

[Drawing 9]

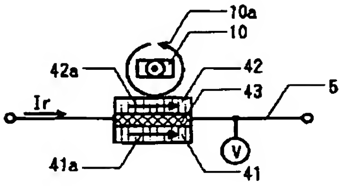


(a)



(a)

[Drawing 13]



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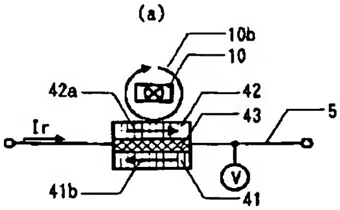
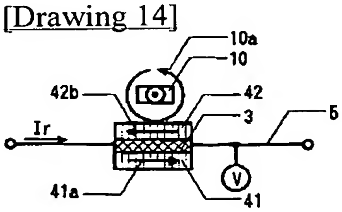
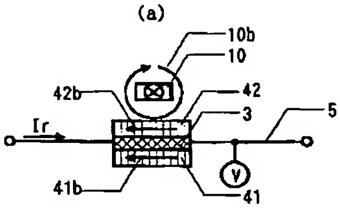


(b)

[Drawing 14]



(a)



(b)

[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law
[Section partition] The 4th partition of the 6th section
[Publication date] July 6, Heisei 13 (2001. 7.6)

[Publication No.] JP,9-91949,A
[Date of Publication] April 4, Heisei 9 (1997. 4.4)
[Annual volume number] Open patent official report 9-920
[Application number] Japanese Patent Application No. 7-244991
[The 7th edition of International Patent Classification]

G11C 11/14

[FI]

G11C 11/14 A

[Procedure revision]
[Filing Date] May 24, Heisei 12 (2000. 5.24)
[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[Proposed Amendment]
[Claim(s)]
[Claim 1] It is the magnetic-thin-film memory device which has the 1st magnetic layer and the 2nd magnetic layer with an parallel easy axis by which the laminating was carried out on both sides of the insulating layer, and is characterized by the holding power of this 2nd magnetic layer having the part from which it is larger than the holding power of this 1st magnetic layer, and the tunnel effect is acquired between this 1st magnetic layer and this 2nd magnetic layer.
[Claim 2] It is the magnetic-thin-film memory device characterized by the difference of the holding power of said 1st magnetic layer and said 2nd magnetic layer being 20 or more Oes in a magnetic-thin-film memory device according to claim 1.
[Claim 3] The magnetic-thin-film memory device characterized by having a write-in line for writing in information, and a read-out line for reading the written-in information further in a magnetic-thin-film memory device according to claim 1 or 2.
[Claim 4] The storage element part from which the magnetic-thin-film memory device according to claim 1 or 2 was arranged in the shape of a matrix and which it consisted of,
The read-out line which connects to a serial said magnetic-thin-film memory device arranged in the one direction,
Magnetic-thin-film memory characterized by having two write-in lines formed in the condition of it having been arranged in the direction perpendicular to a direction respectively parallel to said read-out line, and having insulated mutually.

[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] 0020
[Method of Amendment] Modification
[Proposed Amendment]
[0020] Moreover, the magnetic-thin-film memory device concerning this invention is characterized by the difference of the holding power of the 1st magnetic layer of the above and the 2nd magnetic layer of the above being 20 or more Oes.
[Procedure amendment 3]
[Document to be Amended] Specification
[Item(s) to be Amended] 0021
[Method of Amendment] Modification
[Proposed Amendment]
[0021] Moreover, the magnetic-thin-film memory device concerning this invention is characterized by having a write-in line for writing in information, and a read-out line for reading the written-in information further.
[Procedure amendment 4]
[Document to be Amended] Specification
[Item(s) to be Amended] 0022
[Method of Amendment] Deletion
[Procedure amendment 5]
[Document to be Amended] Specification
[Item(s) to be Amended] 0023
[Method of Amendment] Modification
[Proposed Amendment]
[0023] Moreover, the magnetic-thin-film memory concerning this invention is characterized by to have the storage element part from which the magnetic-thin-film memory device concerning this invention was arranged in the shape of a matrix and which it consisted of, the read-out line which connects to a serial said magnetic-thin-film memory device arranged in the one direction, and two write-in lines formed in the condition it has been arranged in the direction perpendicular to a direction respectively parallel to said read-out line, and insulated mutually.
[Procedure amendment 6]
[Document to be Amended] Specification
[Item(s) to be Amended] 0052
[Method of Amendment] Modification
[Proposed Amendment]
[0052] The magnetic-thin-film memory device is arranged in the shape of a matrix by the part with which drawing 6 indicates the top view (a) and its BB'sectional view (b) of thin film magnetism memory to be, and writes in with the write-in lines 11, 12, and 13, and the part and auxiliary lines 21, 22, and 23 cross at right angles. Here, the magnetic-thin-film memory device put in order in the direction of a write-in auxiliary line is connected to the serial through the read-out line 5. For example, in the part shown in BB'cross section, the part which connects the magnetic-thin-film memory devices 31, 32, and 33 to a serial reads, and it becomes a line 5.

[Translation done.]